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John M. Goodell, Editor

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Approximate Methods in Engineering Design.

The scientific part of engineering work has been so thoroughly developed that it seems superfluous, or a little worse, to consider such a matter as approximate methods of design in some of the more usual engineering problems, especially in view of the justified refinement of computations which characterizes advanced work in such structures as the stiffened suspension bridge and the modern arch rib. As a matter of fact, however, a large part of the best engineering design at the present time is executed by approximate methods and sometimes rather loosely approximate methods, which pass unchallenged in consequence of the frequency of such procedures and the excessive difficulty attending exact methods. It is well, where uninterrupted custom and daily practice have not only sanctioned but actually established with the firmness of demonstration such approximate methods, to examine them critically with a view to determining whether their character is as professionally respectable as their acceptance seems to indicate.

A little careful reflection will show that there are absolutely no strictly accurate methods of engineering design in any line of work whatever. The ideal conditions on which all analyses of stresses in actual structures are based are never realized in the structures themselves. Forces acting at points and stresses, parallel or otherwise, acting upon plane or other surfaces, according to some well-defined law, cannot be found in nature, at any rate in those parts of nature which include engineering operations. The differences between assumed conditions of analysis and the actual conditions of engineering work should be much more clearly recognized than they are. At the same time the recognition of these real conditions constantly confronting the engineer should not lead either to extravagant distortion of analytic theory or to the rejection of such theory. It is the highest excellence of engineering practice to adapt with good judgment the ideal conditions of refined analyses to those materials and conditions with which the engineer has to deal. It is difficult to determine which is the more objectionable, the disregard of theory because ideal conditions cannot be realized, or excessive refinement in the application of methods and results of analysis to the complicated conditions of actual work. Like all other things, there is a happy medium in this field of the engineer's operations, and the greatest difficulty which besets the designing engineer is to find it. There is no higher or more difficult exercise of judgment than that required in the application of exact methods of design to the more or less obscure conditions attending almost any design problem of magnitude.

Perhaps one of the most pronounced of these cases is that of the theory of earth pressure in the design of retaining walls and in a number of important foundation problems. That theory, as expressed by Rankine and others, is one of the most useful applications of engineering science, and yet it is perhaps the most difficult to apply with good judgment so as to produce safe and helpful results. The conditions on which it is founded are rarely, if ever, realized in actual cases. At the same time if the theory is thoroughly understood and judiciously used, it may be and has been applied to many retaining wall and foundation problems where the most difficult material has been encountered and with the most satisfactory and economical results. At first sight such conditions would appear to preclude the use of any theory of earth pressure, but the exercise of good judgment, guided by a thorough knowledge of both the theory and the existing conditions, makes a most useful device of a theory which has probably been subjected to more vigorous criticism than any other used by the engineer.

Again the ordinary methods of design of draw bridges are all of them loose approximations, especially with the irregular varying depth of trusses now so frequently seen. In practically all cases, the moment of inertia of cross-section of the trusses is either explicitly or implicitly assumed to be constant, while as a matter of fact it is an exceedingly variable quantity. Also the formulas of the theorem of three moments are constantly used, and yet the conditions of support assumed in the demonstration of that theorem are practically never found in ordinary draw bridges. These and other sources of material approximation are ignored in the everyday use of design methods. It would be impracticable, in fact absolutely impossible, to make a strictly exact analysis of stresses in a draw span, either rim-bearing or center-bearing; consequently it is imperative to use the best approximation possible, and the methods of ordinary use probably meet the conditions of the problem well enough.

These general observations could be greatly extended, not only in the particular classes of structures which have been named, but in others with which the engineer has to deal, but enough has been stated to show that general design operations have to be pursued along lines of approximation and not by strictly accurate methods. It is not to be assumed on this account that any loose methods of procedure more or less approximate are justified, but rather they show that the designing engineer assumes a very difficult and delicate responsibility, and that he is bound to exert constantly his best efforts in the improvement of his procedures. Where he must accept the fact that he is working for approximate results only, he is bound to make that approximation the best attainable, and it is due to those efforts that methods of design have been so well developed and so highly improved during the past 25 or 30 years.

It is frequently stated that no method of design need be any more accurate in character than the data available. That principle, however, may easily be made to work vicious results. The two elements of design, methods and data, should both be made as nearly correct as possible. It is fundamentally wrong to hold that, since one cannot be correct the other may be equally in error, because the resulting error may easily be the product of the two errors, so to speak. The best practice requires that the data and the methods should each be the best attainable and that any unavoidable error in the one does not justify indifference as to accuracy in the other. It is clear that there should be no excessive refinement of method or data, but what constitutes excessive refinement must lie in the judgment of the engineer to determine. The main point of the whole matter is that constant use of approximate methods and daily familiarity with their operation should not beget undue confidence in them nor bar the way to constant critical scrutiny or effort for farther improvement. There are not lacking catastrophes, some on an appalling scale, which emphasize this observation.

National Control of Sewage Disposal in Great Britain.

The Royal Commission on Sewage Disposal has just reached the logical conclusion from its investigations since its appointment ten years ago and has suggested that the only solution of the whole problem of sewage disposal in Great Britain lies in the appointment of a permanent national board having general supervision of sewage disposal and water supply works. This suggestion has been made a number of times before; the last time it was prominently made in this country was at a discussion of methods of preventing river pollution held by the American Society of Civil Engineers a few years ago. Whoever investigates the subject of sewage disposal with any thoroughness soon finds that it is so intimately connected with that of water supply, in most cases, that the two must be considered together. The degree of purification which sewage must be subjected to before it is discharged into lakes or streams, and sometimes the matter of treating it at all, depends on the subsequent uses made of the water which receives the sewage and upon the extent of the contamination which the sewage causes. The Royal Commission has reached the conclusion that it is manifestly unfair to call for the same degree of purification in every case, for each particular disposal system should be designed and operated to meet local requirements. It is ridiculous to require a town to purify its sewage to a higher degree than that of the stream into which it is discharged, yet this condition has not been unknown in England. It is equally ridiculous that large sums of money should be spent in legal wrangles, which are as wasteful of time as of money, when a national board might settle such disputes promptly and with greater fairness than any general court, unacquainted with all the technical details relating to sewage treatment.

The Royal Commission was appointed in May, 1898, and at the present time but three of its original members retain office. Its investigations have been very thorough; in addition to its own laboratories at Ealing, Dorking, Leeds and London, it has received the assistance of the authorities of many places where sewage disposal on a large scale could be studied. It has been assisted by specialists outside of its own staff, and as a result of all its work, the conclusion has been reached that the question of sewage disposal has outgrown the powers of any royal commission. In a recent address before the Royal Sanitary Institute, Sir William Ramsay, who has been a member of the Commission from the outset, pointed out that there can be no finality in investigations of the nature of those relating to sewage disposal. New researches are constantly extending the domain of science, and in view of the very little that is definitely known concerning the nature of the processes taking place in the purification of sewage and water, it is certain that the future will reveal many important facts now hidden. For this reason, the Commission believes that a permanent laboratory staff should be formed, so that continuous work on the chemical and biological aspects of the sewage problem may be conducted. Another reason for appointing such a national permanent board is the fact that already there are a number of commissions which have charge of a part or the whole of certain English rivers, exercising supervision over the discharge of sewage into them, as well as over other river conditions. The reason that a permanent board will be advantageous in view of the existence of these commissions lies mainly in the fact that the members of the local commissions are generally interested more or less in local business or public affairs and are consequently open to the criticism that their judgment may be biased by their interests. That this feeling exists is shown by law suits that have arisen over decisions made by such commissions. It is believed that if a national board exists, it may be given the power to determine as a court of final resort the equity in all such controversies, thus relieving the courts of a troublesome class of cases. It is believed that such a board would not have to rely on the expert witnesses of both parties to the dispute, but after due investigation by its own experts, as well as a consideration of the evidence on both sides, could settle the matter once for all. The board could further designate what new river commissions should be appointed and thus provide the whole country with these useful bodies.

One of the most important duties suggested by the Royal Commission for such a permanent board is to prepare a description of the water supplies of the entire country, and the local demands for water. The population of the English cities is increasing so fast that the water supply for them is bound to become a source of controversy very soon, and even at the present time there has been some difficulty where two or more communities have wished to secure the same supply. It is believed that the public welfare demands a complete survey of all available water supplies, and their study in connection with the needs of the various communities. The expenses of such a board will not be very large, compared with the importance of its work, according to Sir William Ramsay. He estimates that £10,000 a year will be sufficient at present, and probably for many years to come. In his opinion the visits of inspectors at regular intervals to the various disposal works and to the rivers of the country, and the constant checking of the results of these works by the board's analysts will accomplish a great deal of good in spreading a general knowledge of all improvements that take place. The government already maintains something of this sort in the board of inspectors who carry out the provisions of the so-called Alkali Act, whose work has been of great value to the public and to manufacturers. These inspectors promptly inform everyone on whom they call of all improvements known to them in connection with the abatement of such nuisances as come under the act, and in consequence they have not only improved conditions, but have succeeded in materially reducing the expense of certain parts of the manufacturing processes. There is every reason for believing, according to Sir William Ramsay, that the inspectors of the permanent board in charge of all sewage and water purification would accomplish the same good results in the regular discharge of their official duties.

Wanted—Light Motive Power.

The present situation in aeronautics ought to act as a powerful stimulant to inventive genius. We are apparently nearly ready for the conquest of the air. Inventors have certainly struck the right trail, as the wonderful exploits of Henry Farman and others give evidence. For a long time, in fact from Icarus to Darius Green, those who would fly imitated the goose rather than the eagle, but all attempts at flapping flight were dismal failures. It is only within a quarter century past that men came fully to realize that a bird in soaring flight is merely a self-balancing kite in which automatic adjustment of the lifting planes removes the necessity for a connection to earth. It is hard to assign to any one man the merit of the discovery—perhaps the lamented Lilienthal did as much as anyone to enforce the lesson, while Hargraves with his box kite and Chanute in this country deserve a large measure of credit for pioneering work. The "way of the eagle in the air," as much a mystery a generation ago as it was to Solomon himself, is now fairly well understood. Following artificial rather than natural lines, the gas bag and the lifting screw have enthusiastic advocates. Whatever the device chosen for winning the ways of the upper air, the real difficulty has at the present settled down to adequate driving power. In many respects a well-designed aeroplane would have the advantage over the bird, especially in having independent and powerful motive power. The bird has to use its wings at once for driving and as planes, with the result that in a wind the bird's tactics are exceedingly intricate. Watch a soaring eagle or osprey through a field glass, and his difficulties are very apparent. If he essays a rising spiral he necessarily makes leeway and in a sudden puff his balancing movements have to be made with lightning-like rapidity. The aeroplane, with a steadily pushing screw, leaving the operator free to adjust balance, has mechanically the advantage. As a teacher of flight, by the way, the eagle is far inferior to one of our common butterflies, Anosia Plexippus, who performs evolutions every bit as remarkable but at low speed and right under the observer's vision. The present trouble with the aeroplane is that with the lightest construction available, the motor is still too heavy to lift itself easily. Farman, in spite of his success, has been on the verge of the impossible in every flight. The least trouble with his motor, the slightest drop in speed, means failure, and while his machine floats down rather lightly, as is the case with every properly balanced aeroplane, there is evidently no reserve of power. Even the dirigible balloons like that of Zippelin, while endowed with large lifting power, drive so hard that the largest practicable motor is still too weak to make much headway against anything but moderate winds, so that the same difficulty as with the aeroplanes still confronts one.

Light construction in gasoline motors has now been pushed apparently almost to the limit of reliability, and it is not easy to see how great gains can be made. Possibly the explosion turbine, at present in only the crudely experimental stage, may be developed so as to be available. It seems to have possibilities in the way of lightness that are in excess of anything within the reach of reciprocating engines. It should be possible, too, to pick out hydrocarbons for fuel that would have some advantage over gasoline in weight of fuel supply. There is a chance also of getting some synthetic fuel richer in stored energy than any convenient natural product. The point has now been reached where every little helps. A few pounds saved by using better material more economically disposed, a little improvement in the cooling devices, a slightly richer fuel, all will help in raising the factor of safety by which the motor can more than support itself. The present factor is dangerously near to unity. The electric motor used by the early French experimenters on dirigible balloons seems to be hopelessly out of it, and would still be out of it even if one could supply its energy by "wireless." An engine working at high efficiency from the richest possible fuel seems the one thing needed, running probably at extremely high rotative speed. Since the output increases nearly as the speed there is a probability that speed-reducing gear necessary to keep the propellers running at an economical rate might more than compensate its added weight and slight loss in efficiency. At all events, here is one of the prettiest and most important problems that engineers have ever been called upon to solve. Success is almost within reach. A little improvement will ensure it in at least a moderate degree; any radical gain will make it complete, and win the air for man's domain. How far the coming air ship will work a commercial revolution is another matter: perhaps the effects may be but slight, yet any practical success means at least the extension of human powers into another realm with all the possibilities thus implied.

Resurveys of Small Towns.

The authorities of few of our small towns realize fully what troubles they are laying up for their successors by the wretched lack of proper street surveys and records they permit. Most of these small places are growing quite rapidly, and the land in them is increasing in value; the future of most of them is bright with the promise of better things. Yet, if a surveyor endeavors to locate with reasonable accuracy the bounds of a piece of property, the chances are that he can find neither intelligible records nor any monuments. Consequently he must establish his corners mainly by the exercise of judgment, and if they are unsatisfactory to the owner of adjoining property, there is a chance for the local lawyers to reap rich fees without doing anybody any good. A good many reasons have brought about this condition of affairs. In some cases the surveyors have had no appreciation of the importance of their work, and owed their official positions more to their ability to be good fellows than to run lines properly. Fortunately, the technical schools are now furnishing better trained men for such positions, and the old reproach against county and town surveyors does not hold except in rare cases. Some of the trouble has probably been due to the defective surveying instruments that were employed, and another cause has been the local lack of belief that anything better than a farm survey was a waste of money. The most frequent cause of the defective conditions referred to has been the custom of using temporary objects as monuments, and of keeping incomplete records. The monuments disappeared in the course of time, and when the lines have been rerun no attempt was generally made to mark them properly, nor to file complete records of the survey. In this inchoate condition of affairs the courts are generally obliged to hold that a line which is marked on the land is the correct one, no matter how poorly it was established.

In any town the base for property lines must be the street lines, and the best way of bringing order out of confusion is to locate and monument street lines thoroughly. This will generally mean a complete resurvey of the place, for the existing maps will usually be found altogether too incomplete to be of anything more than a very general guide. It is questionable if the few corner marks shown on these maps can ever be found. Most of the marks indicated are trees, fence posts, big stones and the like, which have long since disappeared. Probably the cheapest way of making a resurvey is to run a line down the centers of the streets and mark on them at the proper points whatever recorded positions can be found. In addition all existing landmarks and property lines can be located on these center lines. If the resulting information is properly recorded in notebooks, it will probably be possible to make a readjustment of the street lines without going to the expense of large-scale maps. An examination of existing landmarks and of recorded bounds for any one street will indicate a few points that in all probability are correct. Taking lines through these points as a basis, the other points can be shifted back or forth so that a straight street or one with a few angles will result. A little diplomacy on the part of the town authorities and the surveyor will probably bring all property owners to agree with these shifted positions of their lines, after which the important corners can be marked by sinking gas pipe or by some permanent but inexpensive substitute. The actual cost of a survey of this sort in a town of 3000 or 4000 population, should not exceed $1,000, including the expense of placing the necessary monuments and preparing a set of records. After such a survey has been made, the authorities of the town can use much more pressure in persuading property owners to build good sidewalks and otherwise fulfil their civic obligations, since there can then be no question about lines and grades.

Tunnel Events at New York.

The recent subaqueous tunneling events in New York are of a character to arrest the attention of even the most heedless resident. When President Roosevelt officially started the train service on the tunnel route under the North River on Tuesday of this week, he inaugurated a public service of great importance. It is safe to say that the governors of New York and New Jersey, the public officials and men high in business circles who were present at the opening ceremonies do not fully appreciate what an important transportation factor the Hudson & Manhattan R. R. will become within a few years on account of its strategic position. Without in any way desiring to belittle the construction achievements of which the new tunnels are the evidence, it is fitting to quote here a statement made by Mr. W. G. McAdoo, president of the railroad company, concerning the part borne in the enterprise by the president of the Hudson Companies, which are building the entire system: "I am glad to have the opportunity of saying publicly that no man in the City of New York deserves greater credit for what has been accomplished than Mr. Walter G. Oakman. This fact would be better known and recognized but for that fine sense of modesty which is one of his dominant characteristics. In the very inception of the enterprise it was Mr. Walter G. Oakman who gave me wise counsel; who made possible the financing of the first company; who, ever since, has been the loyal friend and indefatigable worker. For the past two years, as president of the Hudson Companies, charged with the actual construction work, Mr. Oakman has been at the front, and the Hudson Tunnel System is bigger and better, and will, for all time, be more useful, as a result of the fine judgment he has brought to bear on the many complicated problems that have had to be solved." The financial problems of such a great and novel undertaking are as serious as those of an engineering nature and this tribute to the man who solved them is gladly recorded in this place. But along with that statement should be an additional one, that the enterprise is indebted for its success in a very large measure to the knowledge of men, tact, patience and shrewdness of Mr. McAdoo.

Another achievement just as interesting was the meeting of the headings of tube D of the four tubes of the Pennsylvania Railroad tunnel under the East River. A description of the methods of carrying on the operations was printed in this journal on July 14, 21 and 28, 1906, but no complete statement of all the difficulties encountered and overcome has ever been compiled. The work on these four East River tunnels has been extremely arduous and consequently all connected with it were jubilant when, at 11 a. m. Feb. 21, the shields of this tube met.

Notes and Comments.

Sewage Purification in Frankfort, Germany, was conducted on the chemical precipitation system up to 1902, when a series of experiments showed that the additional effect of the chemicals over the results of plain sedimentation was very slight. The sewage now first passes through a large catchpit and afterwards through rotary screens, where 26 per cent. of the suspended matter is removed. The sewage loses 64 per cent. more of the suspended matter during its stay in the tanks, which are faced with white glazed bricks and provided with special arrangements for flushing out the sludge and for washing. The total clarification effected in this way is 90 per cent. removal of the suspended matter. The greater portion of the sludge is pumped to fields over which it is distributed by movable pipes. The remainder is stored on sludge beds and, after being drained, is given to farmers who cart it away.

The Introduction of Water Meters in Washington, D. C., is now being carried out at a fairly rapid rate, considering the vigorous opposition to their use heretofore. In the year 1906-7, 5872 meters were installed at private residences and were paid for out of the water revenues. The meters are located outside the houses and were set mainly in the highest part of the district where it is most important to check waste of water. The work of metering the residence services will be continued as rapidly as funds permit, and is one of the most important undertakings of this nature the country has seen. It is usually customary to charge most of the waste of water in a city to manufacturing plants, yet in Washington, which is without such works, the amount of water required is excessive. Repeated investigation has shown that there is a great amount of waste of water supplied to residences, and the records of draught before and after metering residences will accordingly prove instructive.

Vocational Education is very popular in Belfast, Ireland, where a fine building has recently been opened for the Municipal Technical Institute. There are thirteen courses of studies including technical courses in mechanical and electrical engineering, textile industries, pure and applied chemistry, mathematics, woodworking, pointing and decorating, plumbing, handling and spinning flax, weaving, bleaching, dyeing and analyzing waters and dye materials, modern languages, short-hand, book-keeping, commercial forms, drawing, cookery, dress-making, millinery, laundry work and lace making. This school receives the hearty support of the local labor unions and other trade organizations, which encourage the apprentices and young journeymen to take advantage of the instruction, particularly in the evening classes.

The Metropolitan Railway, of London, has now been completely electrified, speaking generally, so far as its passenger traffic is concerned. In the second half of 1907 the aggregate distance run by steam passenger trains was 150,167 miles, while electric passenger trains covered 1,545,149 miles. Freight trains made 102,644 miles. In the second half of 1906 the distance run by steam passenger trains was 523,583 miles, by electric passenger trains 825,897 miles and by freight trains 96,758 miles. The locomotive and electric current charges were £73,561 in the second half of 1907, as compared with £68,807 in the second half of 1906. This shows a reduction by electrification to 19.6 cents per train-mile in the second half of 1907 from 22.8 cents in the second half of 1906. It seems to be the general opinion in British engineering circles that electrification has made good on this line. While it has caused a heavy addition to the capital charges, electric operation has made it possible to meet competition for passenger business by a great extension of the service without materially adding to the expense.

Smokeless Combustion with very low-grade bituminous slack is effected at the shops of the Chester B. Albree Iron Works Company, Pittsburg, Pa., by the simultaneous combustion of the slack and natural gas. The former costs but little over $1 per ton delivered at the works, including cartage, and was found very difficult to burn, as well as very smoky. When burned in conjunction with a small amount of natural gas, however, the latter effectively introduces an excess of oxygen and the heat necessary for ignition of the volatile gases of the fuel, with the result that perfectly smokeless combustion is secured. The coal is burned on plain stationary grates, while the gas is introduced through five small jets inserted in 4 in. open thimbles in the side walls of the setting, about 12 in. above the grate level, so that the gas flames play over the entire fuel bed. Both fuel systems had previously been installed to enable either to be used, without, however, becoming wholly dependent on either one. Although the gas, which costs 10 cents per 1000 cu. ft., is now used principally to promote the combustion of the coal and prevent smoke, the result is said to be a noticeable economy, the power production at the works being obtained at a materially lower monthly cost than if either fuel were used alone. The most satisfactory results were obtained by decreasing the opening between the bridge wall and shell of the boiler very materially and admitting an excess of air under and over the grates, the bridge opening being reduced to an annular space, 5 in. wide, conforming to the shape of boiler shell. While all cities are not so fortunately situated that natural gas is available at low rates, there are many where it can be obtained at a price that makes it worth while to try this system of firing from the standpoint of saving expense, apart from that of reducing smoke.

THE WATER SUPPLY SYSTEM OF LOS ANGELES, CAL.

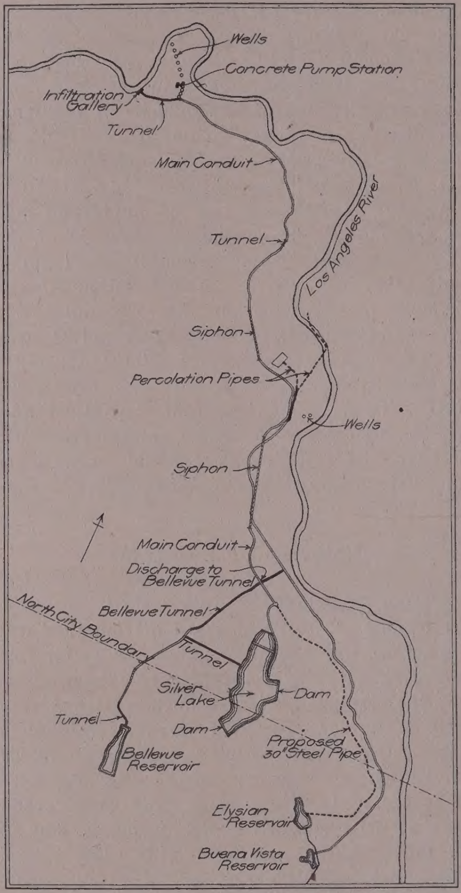
The water supply of Los Angeles, California, is at present obtained almost entirely from the flow of the Los Angeles River. This stream has its source in the broad San Fernando Valley at the base of the southerly slope of the Sierra Madre Mountains, some 20 miles to the northwest of the city, and flows in a generally southeasterly direction to the northern corporate limits; at this point it makes a turn of nearly 90 deg., from which it continues through the city and is dissipated in the broad, sandy plain between the latter and the Pacific Ocean, some 18 miles from the southern city limits. The original pueblo of Los Angeles, founded in the early days by the Spanish, was given the right to all of the waters of the Los Angeles River. This grant has been held by the courts to remain in force at the present and to convey the right for the city to use all of the water, including the underground as well as the surface flow, which passes through a narrow canyon at the point where the direction of the course of the stream changes near the northern limits of the city.

The rights thus granted were transferred to a private organization in 1868, with certain restrictions concerning the distribution of water within the city. In 1902 the works of the Los Angeles City Water Co., which was then operating under this transfer, were purchased by the city by making a $2,000,000 bond issue. Since then the works as they existed at that time have been practically rebuilt and have been more than doubled in capacity to keep pace with the remarkably rapid growth of the city. The rate of the growth of the population in Los Angeles in recent years is one of the most notable instances in the development that is taking place along the Pacific Coast. In 1890 the population of the city was 50,395, in 1900 it had doubled, and a recent census places it at nearly 275,000. This tremendously rapid increase in the number of people to be furnished with water from the distribution mains has required the construction of extensive works to secure and deliver into the city a large quantity of water in addition to that which was required when the municipality purchased the works of the private company. At the same time, entirely new districts that have been opened meanwhile are now completely built up and the older districts of the city have become much more congested, so that a vast amount of new construction has also been required on the distribution system.

Some years ago it became evident that the supply which could be obtained from the flow of the Los Angeles River was entirely inadequate to meet the demands which might be expected in the immediate future. In fact, the additional quantity requisite each year could be obtained only by the construction of extensive new works on the supply system. The conditions existing in the San Fernando Valley are such that the limit to which these new works can be carried without taking more water from the valley than is delivered to it, has been determined and is scarcely enough to meet the present demands, if a series of dry years should occur. On this account, it became imperatively necessary to obtain an additional supply of such capacity as to insure enough water to meet the reasonable demands that may be expected for a considerable period in the future, based on the rate at which the city may reasonably be expected to grow.

Extensive investigations determined that the supply available in the Owens River Valley is the most feasible one to obtain. Accordingly, the decision was made to build an aqueduct approximately 215 miles in length to deliver this supply to the city. The reasons for making this decision and an outline of the plans for the aqueduct were given in The Engineering Record of Nov. 3, 1906, and Jan. 26, 1907, respectively. Meanwhile, during the construction of this aqueduct the water department of the city is confronted with the necessity of developing, from time to time, an additional quantity of water in the San Fernando Valley to meet the rapidly increasing demands. The completion of the aqueduct at the earliest possible time is, therefore, an imperative necessity.

The works which have been built to develop the requisite additional supply since the city obtained the system have been extensive, and have necessarily involved much unusual construction, owing to the existing conditions. When the system was purchased in 1902, a conduit 5 miles in length, known as the Crystal Springs conduit, extended from an intake at a gate house in the San Fernando Valley to two distribution reservoirs in the northern part of the city. This conduit was supplied by two lines of pipe laid with open joints in the gravel which forms the bed of the valley, and delivered from 20 to 24 cu. ft. per second. A pumping station in the city, with a capacity of 13,500,000 gal. per day, was furnished with water from one of the reservoirs supplied by the conduit. This station had been installed to deliver to the higher districts which could not be reached by gravity from the existing distribution reservoirs, and was supplemented by two smaller stations supplying isolated high districts. These reservoirs and pumping stations comprised the available means of supplying the distribution mains and were entirely inadequate.



Conduits and Reservoirs, Los Angeles Water Supply System.

The first new work undertaken by the city, therefore, was to obtain more water. The surface flow in the Los Angeles River is remarkably steady, with the exception of large floods of short duration during the rainy season. The San Fernando Valley in which the river has its source has an area of approximately 200 sq. miles, and is surrounded on all sides by hills and mountains, the whole watershed, including hills and valleys, being about 500 sq. miles. The only outlet from this valley is a narrow canyon in the hills, through which the Los Angeles River passes out of it. The entire valley is underlaid by a water-bearing bed of gravel of great depth, resulting in an immense underground reservoir of quite definite limits, which is supplied chiefly by the run-off from the rocky sides of mountains above the valley to the north. The outlet canyon through which the river flows is also apparently the only outlet for a heavy sub-surface flow from this underground reservoir.

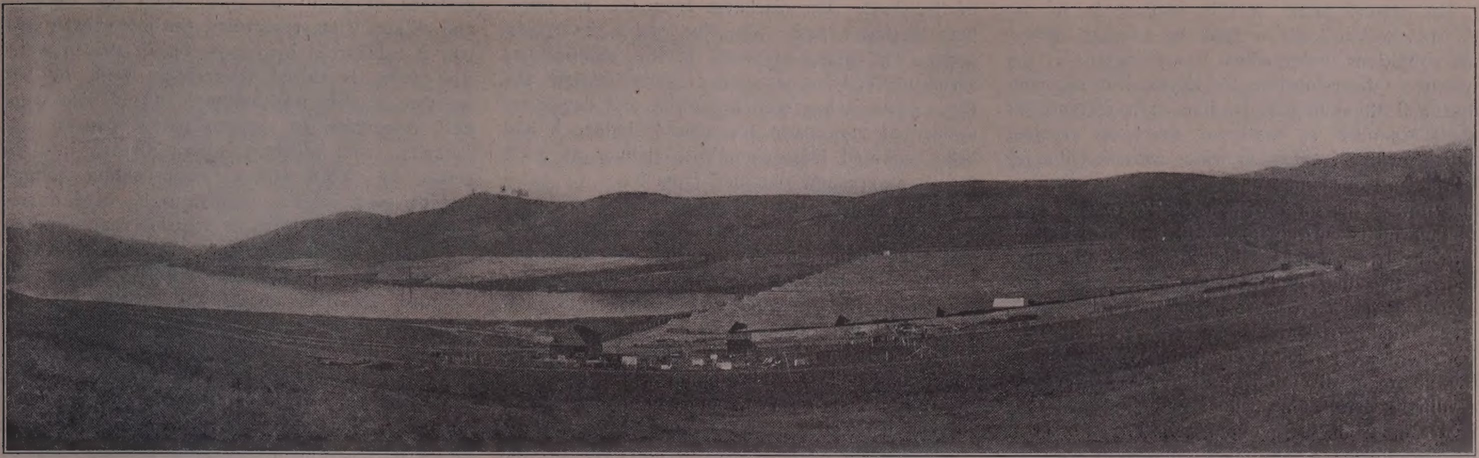
The two double lines of pipe laid with open joints in the gravel at the upper end of the Crystal Springs conduit were supplied chiefly with water from the underground reservoir. One of the lines, however, was laid across the river channel and received some water from the surface flow in the latter. These two lines were both of vitrified clay sewer pipe, ranging from 12 to 24 in. in diameter, and were laid about 14 ft. below the surface. One line was 3,000 ft. long and the other 1,600 ft., the two producing at times as much as 11 cu. ft. of water per second. Later, however, the joints between the pipes became filled with roots and silt, with the result that the quantity of water delivered from them was much reduced.

As water could evidently be developed in the gravel by properly built collecting works, an infiltration gallery adjacent to the two lines of open-joint pipe has been constructed since the city obtained control. This gallery is 2,500 ft. long and extends across the channel and flood plane of the river from the gate house at the upper end of the Crystal Springs conduit to which it delivers. The gallery consists of a horseshoe shape concrete conduit, 5 ft. wide and of the cross section shown in an accompanying illustration. The curved invert of this conduit was built in sections, 18 in. wide, which were cast on the surface and then placed in the trench. Each section is reinforced with a ¾-in. rod that extends above both ends of the section far enough to be bent in a hook. Tongue and groove joints were made between the sections and between the arch ring and the sections. These joints were left open as the sections of the invert were laid, to permit the entrance of water from the gravel. The arch ring was built in place and was reinforced with 5/16-in. iron-wire cable, placed as shown. The arrangement of the cable reinforcement in the sides of the conduit-barrel was such that the hooks on the ends of the bars in the sections of the invert could readily be engaged by it, thus producing a practically continuous structure.

The gallery was built in a trench, 7 ft. wide and from 12 to 18 ft. deep, in the water-bearing soil. The construction under the hazardous conditions thus presented was rendered comparatively easy, however, by using steel sheet-piling. The latter was driven in advance of the excavation and after the gallery had been completed was pulled and used again.

This infiltration gallery and the two lines of open-joint pipe deliver a constant flow of about 6,000,000 gal. a day into the Crystal Springs conduit. The dependable surface flow of the river at the upper end of this conduit is also about 13,000,000 gal. per day. The total normal quantity delivered to the conduit is, therefore, 19,000,000 gal., or about 30 cu. ft. per second, while the carrying capacity of the conduit is 50 cu. ft. per second and can all be utilized during periods when more water is available, the excess being delivered to reservoirs in the city.

The gate house at the upper end of the Crystal Springs conduit is at the point of a high hill



Finished Roof of Ivanhoe Reservoir and Upper End of Silver Lake Reservoir, with Sluicing of Dam Material in Progress.

which marks the end of a spur of low mountains. The conduit starts from the gate house as a tunnel, 3,433 ft. long, through the hill. The cross section of this tunnel is somewhat egg-shape, with the small end up and the invert flat, the extreme height and width being 6 ft. and 4.5 ft., respectively. The material through which this tunnel was driven consists mainly of a hard, dark-colored shale, which slacks on exposure to dry air, but remains stable without support for about half the length of the tunnel, due to dripping water in the latter. The balance of the tunnel is either timbered or lined with brick, The balance of the tunnel, an open cut, 2,679 ft. long, was made for a conduit having a concrete invert and a brick arch. This conduit has a horse-shoe shape section with a width of 54 in. at the springing line of the arch. A 44-in. riveted-steel pipe carries the water from the end of the conduit in the open cut for 19,152 ft. to another tunnel, 1,336 ft. long, that terminates in the Buena Vista distributing reservoir, one of the two supplied by the Crystal Springs conduit. About half of this tunnel is lined with brick, and the balance is in self-sustaining sandstone.

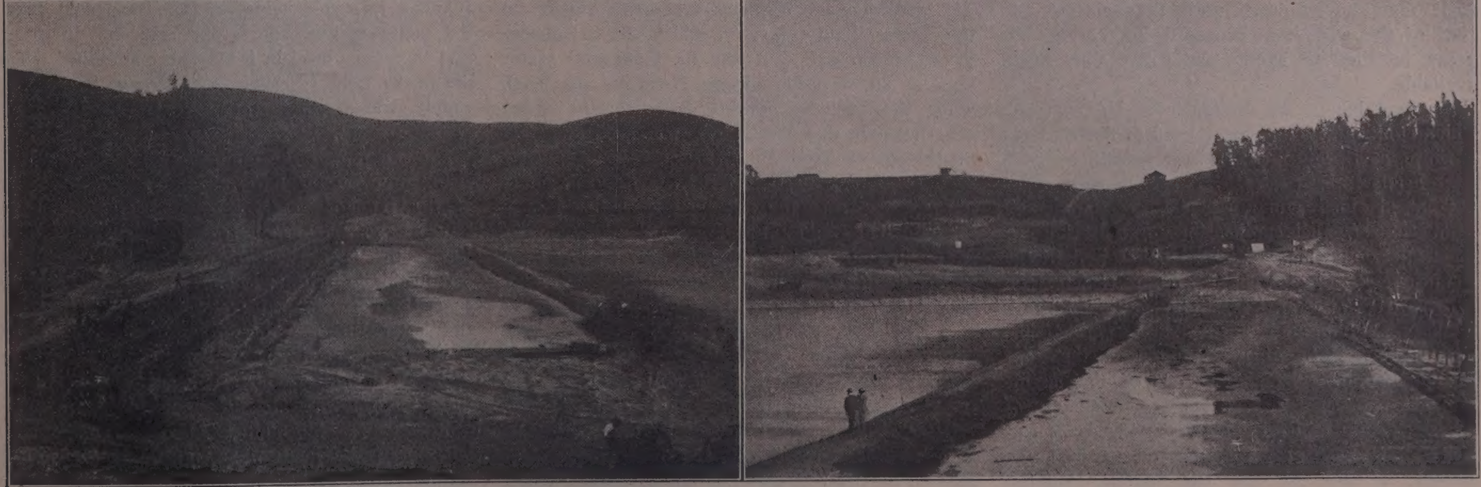
A branch is taken from the Crystal Springs conduit at a point 2,185 ft. below the upper end of the 44-in. steel pipe section to supply the Bellevue distributing reservoir, the other one of the two to which this conduit delivers. The first 4,785 ft. of this branch is in a tunnel of the same general cross section as the one on the upper end of the conduit. A brick lining was placed in 2,828 ft. of this tunnel, but the remainder is in self-sustaining sandstone. The next 5,537 ft. of the branch is in a horse-shoe shape conduit, with a concrete invert and a brick arch, the width being 48 in. at the springing lines of the arch. In this distance three ravines are crossed by means of 48-in. steel siphons, having an aggregate length of 1,362 ft. The last 500 ft. of the branch is also in a tunnel that terminates in the Bellevue reservoir.

A conduit entirely distinct from the one from Crystal Springs, termed the Main conduit, has been built since the system was purchased by the city. This conduit is approximately 5.5 miles in length, and follows along the hills at an elevation 60 ft. above the Crystal Springs conduit. At present, it is supplied by an infiltration gallery of exactly the same type as the one at the head of the Crystal Springs conduit, by an infiltration tunnel in rock and by direct diversion of the surface flow in the river. Plans have been made to extend the infiltration gallery across the valley of the river, in order that the stream flow may be extracted from the underlying gravels by gravity. This arrangement is proposed to guard against danger of the contamination of the water above this point. The various sources of supply at the head of this conduit insure a constant flow of 11,500,000 gal. This flow can be augmented in an emergency by pumps in a station adjacent to the gate house, which pumps draw from six wells driven in the gravel and can deliver 5,000,000 gal. per day.

The infiltration gallery and tunnel deliver to the lower part of a concrete gate house and the surface flow is diverted into this same house. The first 2,001 ft. of the conduit is in a tunnel which starts in the gate house at an elevation 20 to 30 ft. below the level of the sub-surface flow of the stream. This tunnel was driven in solid granite rock, but enabled a long bend in the river to be avoided. The balance of the Main conduit follows generally along the contours on the sides of the hills and is built of concrete, except for two 52-in. riveted-steel siphons which cross two canyons, with an aggregate length of 5,795 ft., and a short tunnel through a hill. At the point where the tunnel on the branch of the Crystal Springs conduit leading to the Bellevue reservoir is crossed by the Main conduit arrangements are made to deliver water into that branch. Some 1,200 ft. below this crossing the Main conduit terminates in a division gate house, from which it is continued to the Ivanhoe distributing reservoir. A 30-in. main is also to be laid from this gate house to supply another distributing reservoir, the Elysian.

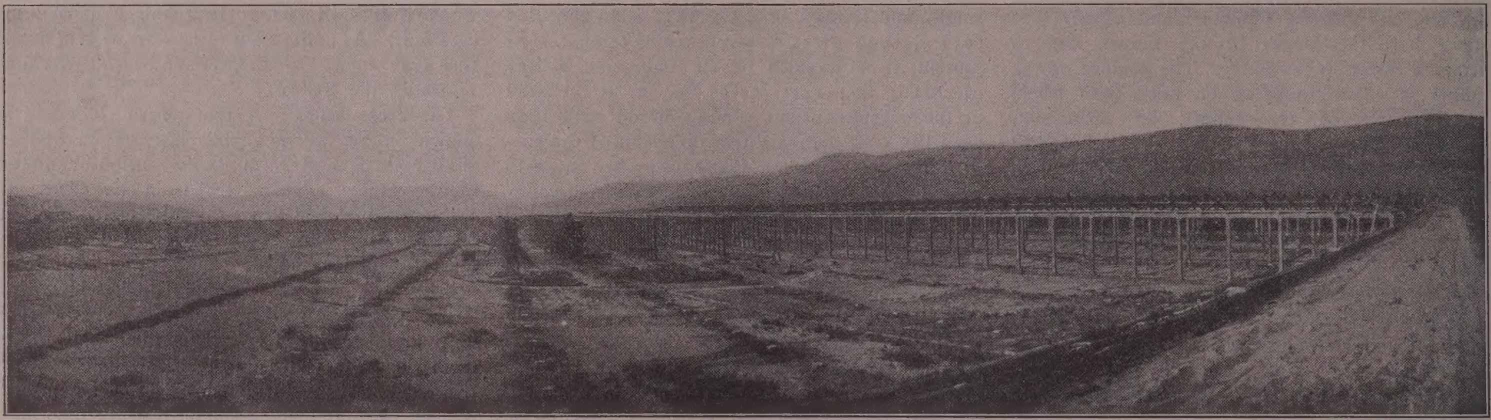
The cross section of the concrete conduit is shown in an accompanying illustration, and is similar in general form to the various conduits of the supply system. It has a net area of 17 sq. ft., and is laid to a grade, which gives it a carrying capacity of 45 cu. ft. per second. In most of its length this conduit was built in a bench cut just above a supply ditch which was formerly used to deliver water into the city from an intake on the river. This ditch had to be maintained in service during the construction of the conduit, thus involving a great amount of difficult work. Notwithstanding this condition, the conduit was built in about seven months.

The pumping station at the narrow canyon which forms the outlet of the San Fernando Valley has been entirely rebuilt recently and the equipment in it replaced by modern pumps. The first of the new units to be installed was a 7,000,000-gal. cross-compound high-duty Snow steam pumping engine. This pump is supplied under a suction head of 40 ft. from the Buena Vista distributing reservoir, which is in the canyon immediately above the station, and discharges into a high-service system against a static head of about 290 ft.



Two Views of Silver Lake Reservoir Dam under Construction, Los Angeles Water Supply System.

The second pump at this station is of an unusual design, built to meet the peculiar operating conditions under which it was installed. Between the diversion into the Crystal Springs conduit and the pumping station, in a distance of about 5.5 miles by the river, the latter receives enough water from other water courses tributary to the San Fernando Valley to cause a considerable flow at the station when the flow of the river farther up is entirely dry, due to the diversions into the two conduits. These streams and other causes also increase the sub-surface flow sufficiently at the narrows to permit a comparatively large amount of water to be removed at the station, without reducing the quantity available at the upstream diversions. Eight wells were accordingly driven on a line extending generally upstream from the pumping station and across the flood plane of the river to a point near the mouth of the Arroyo Seco, a water course which is generally dry, but which carries large volumes of water under certain conditions. These wells were 150 to 350 ft. apart, and by means of them the top of the bed rock was determined at an elevation of 75 to 97 ft. below the surface. Over the rock is a deposit of river detritus, consisting principally of sand and gravel in which a large sub-surface flow occurred even when the river bed was entirely dry. As a result of these investigations, the decision was made to drive a gallery in the rock from a shaft in the pumping station, on the line of the wells and at an elevation low enough to provide an ample rock roof; then continue the wells down until they pierced the roof of the tunnel.



Roof of Ivanhoe Distribution Reservoir under Construction, Los Angeles Water Supply System.

A 14-ft. concrete-lined shaft was accordingly sunk to a depth of 115.5 ft. below the level of the floor of the pumping station, within the walls of the latter. The gallery was driven for a distance of 2,500 ft. from the foot of this shaft, with a cross section generally the same as the standard tunnel section of the supply system. The wells were then driven down until they pierced the roof of this tunnel, as proposed, and the second pump installed to handle the water thus made available.

A pump had to be designed for this purpose which could lower the water level in the shaft as much as 80 ft. and could deliver against a maximum head of about 150 ft. As such a pump could not be obtained under a guarantee from any manufacturer, the engineering organization of the water department designed one suited to the conditions and had it built at the Risdon Iron Works, of San Francisco. This pump is driven by a cross-compound horizontal steam engine, with a tail-end fly-wheel, mounted on the floor of the station. The piston rods of this engine are each connected to a rocker arm at the top of the shaft, and each of the two rocker arms carries a 95-ft. vertical connecting rod attached to a plunger in one of the two pump cylinders mounted on a concrete foot block in the bottom of the shaft. The discharge from the two cylinders is into a 24-in. pipe line under the 150-ft. head. The pump arranged in this manner has given perfectly satisfactory results during the three years it has been in service and developed a duty of 117,000,000 foot-pounds before it had been operated long enough to deliver as good results as are now obtained from it.

Steam to drive the two pumps in this station is supplied by a battery of two 250-h.-p. Stirling water-tube boilers fired with crude oil. An addition is being built to the station building to provide room for a second 7,000,000-gal. horizontal cross-compound steam pumping engine, built by the Risdon Iron Works, and two 350-h.-p. Stirling water-tube boilers. This pump will draw from the Buena Vista reservoir and will supply a high-service district.

Distribution System. The topography of the city is quite favorable toward a satisfactory location of distribution reservoirs and an opportunity to deliver a large proportion of the supply by gravity. The area included by the corporate limits of the city was originally a rectangle, 6 miles from east to west and 6 miles from north to south. The city has been greatly extended toward the southwest from this original rectangle during the last few years. A range of hills occupies the northern part of the rectangle and slopes away quite abruptly to the south. The business section and the more densely populated resident districts are adjacent to these hills, a large proportion of them being so situated that they can be supplied by gravity from reservoirs located on the hills.

The two original distribution reservoirs, the Buena Vista and the Bellevue, to which the Crystal Springs conduit delivers, supply by gravity the section of the city lying at the lowest elevations. This low-gravity system includes most of the older residence districts and all of the extensive residence additions toward the southwest. The system was originally dependent chiefly on the Buena Vista reservoir, which has a capacity of 13,000,000 gal. and has its maximum water level at an elevation of 374 ft. above sea level, while the business section is generally about 260 ft. above that level. The increased demands on the system from the business section and the need for higher pressure for fire purposes made it necessary to supply this section from a higher system. The rapid extension of the outlying residence districts to the southwest also rendered the Buena Vista reservoir inadequate some years ago, so the Bellevue reservoir was built to supplement it. The Bellevue reservoir is in the extreme northwestern part of the city, with its high water line at elevation 380, and is located so the new residence districts may be reached more directly from it. This reservoir is lined with concrete and is covered with a light wooden roof carried by concrete columns and girders.

Toward the southwestern part of the city, at a distance of about 10 miles from the Bellevue and Buena Vista reservoirs, the low-gravity system is reinforced by two series of driven wells. The water is raised from these wells by two separate air-lift installations, and is discharged into reservoirs of approximately 600,000 gal. capacity, from which it is sent directly into the mains by steam-driven, reciprocating pumps, serving as a reserve supply, to be used during seasons of heavy draft, as occasion may require.

An intermediate residence district, lying at a higher elevation than that portion of the city supplied by the low-gravity system and the greater portion of the business section are supplied by the high-gravity system. This system is dependent on four reservoirs for supply and pressure. One of these, the Elysian, is higher up in the same canyon in which the Buena Vista reservoir is located, and has a capacity of 10,500,000 gal. It is lined with concrete and covered with a light wooden roof. Water is at present delivered to this reservoir by the 7,000,000-gal. Risdon pump in the adjacent station; but, when the 30-in. line from the division gate house on the Main conduit is built to this reservoir, a large portion of the water will flow to it by gravity.

The two other principal reservoirs of the distribution system are together in a saddle in the range of hills along the northern part of the city. One of these is the Ivanhoe reservoir, to which the Main conduit delivers; the other is the Silver Lake reservoir. The Ivanhoe reservoir has a capacity of 46,550,000 gal., and was developed by constructing an earthen dam across the canyon at each end of its site. The Silver Lake reservoir has recently been built for impounding purposes, and has a capacity of 100,000,000 cu. ft. An earth dam 3,600 ft. down the canyon from the lower dam of the Ivanhoe reservoir, and a smaller earth dam along one side of the site develop the Silver Lake reservoir. The high-water line in both reservoirs is at Elevation 447, the Ivanhoe reservoir being, in fact, separated from the upper end of the larger reservoir in order that the water level in it may be maintained when the Silver Lake reservoir is at a stage too low to supply water other than to the low-gravity system.

The portion of the main conduit from the division gate on the latter extends along one side of the Ivanhoe reservoir to the upper end of Silver Lake. A branch from this conduit is laid across the upper end of the Ivanhoe reservoir and in this branch are seventeen openings, equally spaced across the reservoir, the water entering the latter through these openings. The outlet from the reservoir is made through a similar series of openings, which deliver to a 36-in. main that conveys water to the high-gravity distribution system. This main is also connected to the portion of the low-gravity system in the southwestern part of the city, and to that system in the central congested portion of the city as well.

The outlet from the Silver Lake reservoir is through a concrete tower toward the upper end of the latter. This tower connects with a tunnel 2,465 ft. in length, which extends under an adjacent hill to a connection with the branch of the Crystal Springs conduit leading to the Bellevue reservoir. The latter can thus be supplied from three sources, directly from the Crystal Springs conduit, by the connection between the branch of that conduit and the Main conduit, and from Silver Lake, rendering it particularly dependable.

Both the high and low-gravity systems are thus arranged with the two main distribution reservoirs on each of them. These reservoirs are also so located that the trunk mains leading from them to the system which they supply form a loop in each case. A supply may thus be delivered to both systems in two independent and entirely distinct ways. This arrangement is particularly desirable, since it not only balances the pressures in the systems, but is also a valuable safeguard in an emergency.

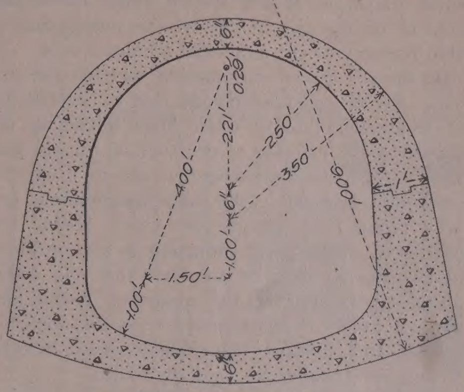
Considerable areas in the northern part of the city above the level reached by the high-gravity system are supplied by a high-service pumping system. The 7,000,000-gal. Snow pump in the station at the Narrows delivers to this system under a pressure of about 100 lb. The Solano reservoir, with a capacity of 6,000,000 gal., is placed at one end of the trunk line of this system, and the Highland reservoir, with a capacity of 5,500,000 gal., at the other end. These two reservoirs are about 5 miles apart and effectually regulate the pressures on the high-service system. their flow lines being at 611 and 613 ft., respectively, above sea level.

Lying at the extreme high points in the city are two isolated districts, each of which is supplied from a small separate system. One of these is adjacent to the Silver Lake reservoir and is supplied from a small pumping station at the latter, this station delivering to a 530,000-gal. regulating reservoir during low demands. The other elevated district is close to the Highland reservoir and is supplied from the latter by a small pumping station, which delivers to a 760,000-gal. regulating reservoir on the hills above it.

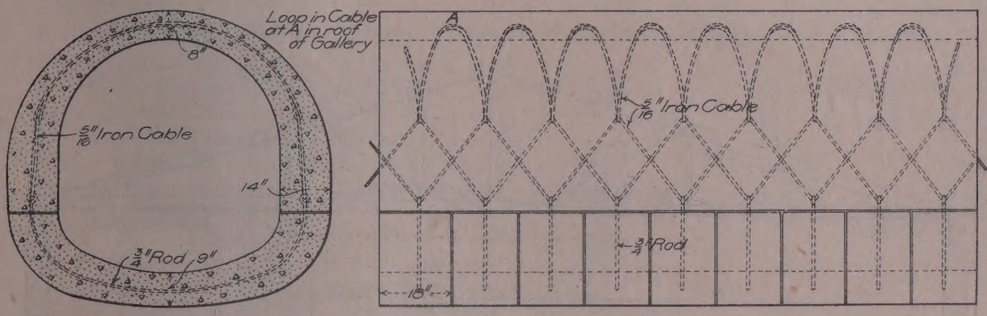
All of the reservoirs, with the exception of Silver Lake and Buena Vista, are covered with light wooden roofs to prevent algae growths, as the latter are remarkably heavy in uncovered small reservoirs in this region. The Silver Lake covers an area of 95 acres, however, so could not be roofed, but it is believed the life balance between organisms in a reservoir of this size may prevent any trouble.

On account of the demands on the Buena Vista reservoir the water in it is constantly changing, hence growths of algae are impossible in this reservoir. The sides of this reservoir being of rubble masonry and the bottom of rock, also tend to prevent such growths.

The type of roof used in covering the Bellevue and Ivanhoe reservoirs is shown in an accompanying illustration. Years of experience in covering reservoirs under the conditions presented demonstrated conclusively that a perfectly tight roof was not essential to prevent the growth of algae and other organisms in stored water; in fact, a moderate amount of shade has been found to produce the desired results. On the other hand, no provision has to be made in this climate to carry snow loads. The lightest roof which would provide a covering could, therefore, be built. Previous experience with other roofs showed also that wooden columns to carry the roof of a reservoir in which the water level varied constantly would soon decay. Consequently, in the roof for the Ivanhoe reservoir, which has recently been finished, and for the new roof over the Bellevue reservoir, which is being built, concrete columns are used.



Section of Main Conduit.

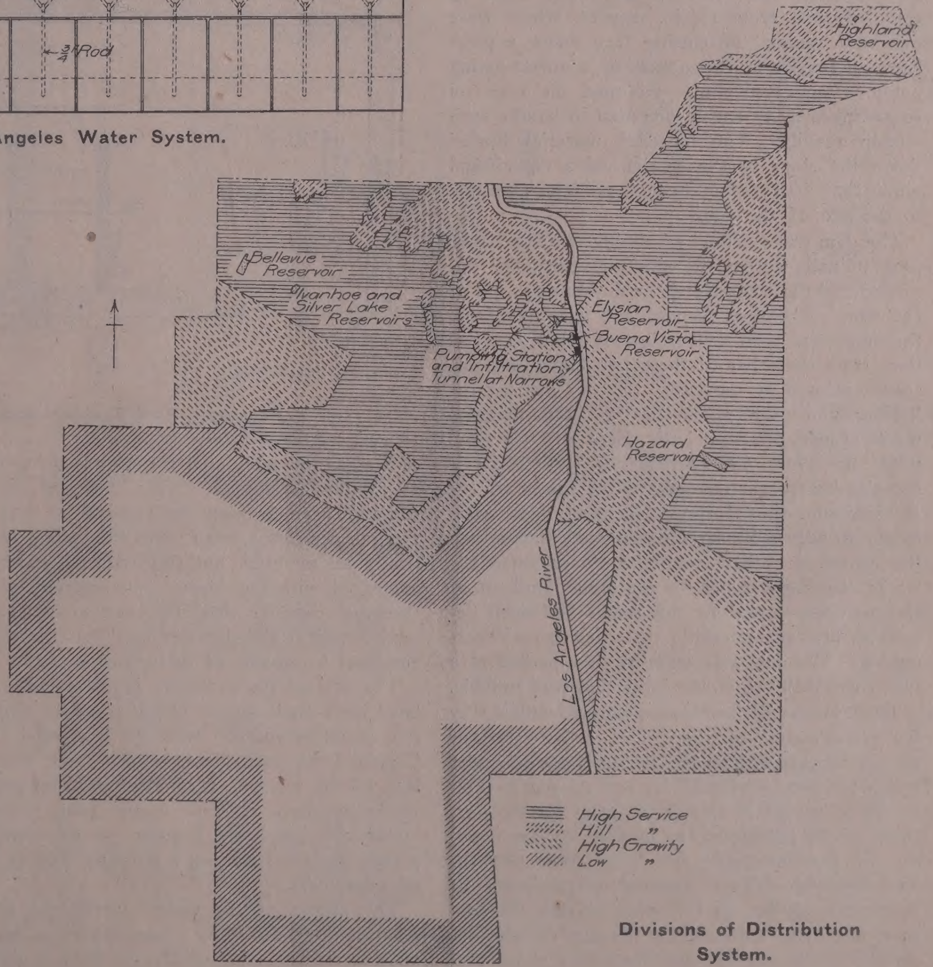


Infiltration Gallery Conduit, Los Angeles Water System.

The columns of these reservoir roofs are in regular longitudinal rows, 40 ft. apart, with the columns in the rows spaced 16 ft. apart on centers. The columns are built on spread footings and are reinforced as shown in the illustration. Each longitudinal row of columns is capped by a continuous 8 x 14-in. reinforced-concrete girder. The roof is carried on these girders by transverse 40-ft. span light wooden trusses, built up to 1 x 6-in. and 2 x 6-in. plank. These trusses are spaced 8 ft. apart on centers, with a rafter midway between them. The roof covering consists of 1 x 12-in. plank nailed to the trusses.

The roof of the Bellevue reservoir covers nearly 5.2 acres, and the one over the Ivanhoe reservoir 9.5 acres, so their construction involves a large amount of work. The Ivanhoe roof was built in 9 weeks, however, and the one at Bellevue in 6. The concrete columns and girders were cast in sectional forms, which are arranged so they could be taken down and re-used several times. The concrete was made in the proportions of 1 part Portland cement and 6 parts gravel. It was made in a concrete mixer set upon the bank at one side of the reservoir and delivered into place in wheelbarrows.

The wooden trusses after being assembled on the ground could readily be hoisted into place, as they only weigh about 400 lb. each. One of these trusses was loaded with 6.5 tons suspended at the center before it was destroyed, showing that they are amply strong.



Divisions of Distribution System.

The Ivanhoe reservoir was built in 1904, but has only recently been roofed, as stated. Meanwhile, the inner slopes of the two dams which form it, and the natural slopes along its sides had to be protected from wave action, as the position of the reservoir exposes it to the full sweep of the highest winds which occur in this region. At the time the reservoir was built funds were not available, nor was it deemed necessary to line the slopes with concrete or rip-rap. As a substitute for such lining the inner faces of the dams, which are on 2½ to 1 slopes, and the 4 to 1 natural slopes along the sides were given two heavy coats of crude California asphalt-base oil. The ground was stirred up to a depth of 2 or 3 in. before the first coat was applied, and this coat was permitted to harden before the second was added. Both coats were covered while fresh with a thin layer of sand. The slopes were protected in this manner at a very reasonable cost and withstood for three years, without any apparent deterioration, the force of the high waves resulting from the winds to which the reservoir is exposed. At the same time, the outer face of the downstream dam was covered with a single coat of oil applied to the slope as it was finished. This application entirely protected the sandy clay soil of the dam from washing during three winters of excessively heavy rains.

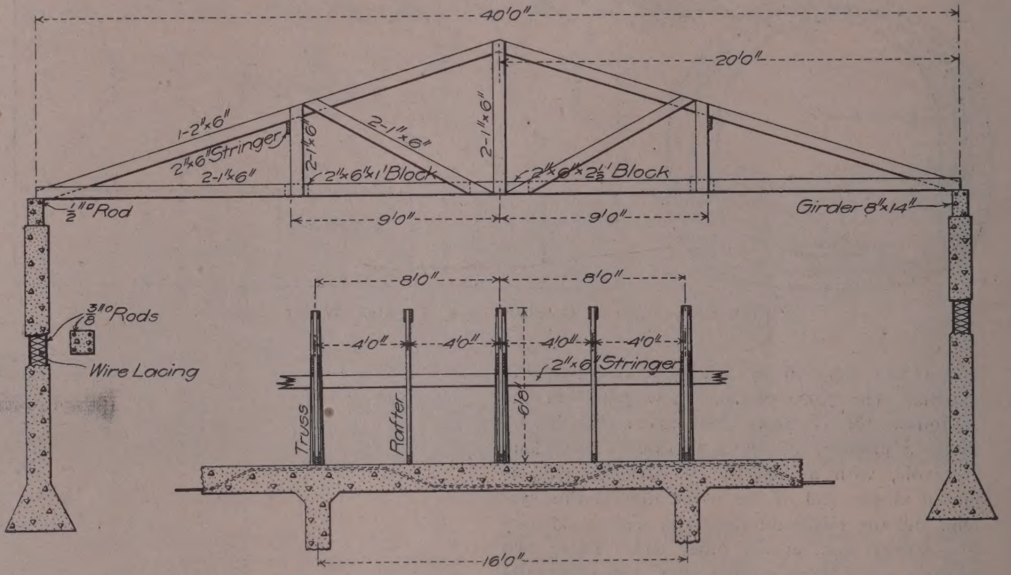
The main dam of the Silver Lake reservoir is within 5 ft. of the finished height. When completed it will have a maximum height of 54 ft., will be 20 ft. wide and 950 ft. long at the crest and will have 2½ to 1 slopes on both sides, containing approximately 140,000 cu. yd. of material. The dam was built entirely by the hydraulic-fill process with material obtained from the area to be submerged. This material is a sandy clay of excellent character for the purpose. The center area from which it was obtained is about 2,000 ft. upstream from the dam, the original slope of the ground in this area being about 3½ or 4 to 1. The material was loosened from this slope by three streams from 1½-in. nozzles, which were delivered against the cutting face under a pressure of 100 lb. at the nozzle by a direct-acting pump. Each nozzle was mounted on a swivel so arranged as to enable one man to handle each stream readily. The loosened material flowed down the slope to the suction of a centrifugal pump that delivered it through an 8-in. pipe line to the site of the dam.

The dam was started by building two low banks longitudinally across the site, one along the upstream and the other along the downstream toe of the dam. The flow through the pipe line from the pump was then delivered, first from one, and then from the other of these two banks into the space enclosed by the latter. In this manner the heavier and coarser particles of the material were deposited along both faces of the dam, while the light, fine particles of clay which it contained were carried toward the center of the embankment, thus forming an ideal dam. The banks on both sides were maintained higher than the center, in order to hold between them the water discharged from the pipe lines until all of the material carried by this water had been deposited, and also to settle the embankment thoroughly. The dam was built by this method at a unit cost much below any other that was suitable.

The amount of storage rendered available by the construction of the Silver Lake reservoir greatly relieves the danger of a shortage of water which has been presented for several years. Following a period of dry years prior to the purchase of the private works by the city, the quantity of flow available from the river and the San Fernando Valley reached a minimum of 34,250,000 gal. per 24 hr., while during the past year the daily consumption during certain dry periods in the summer was somewhat above that amount. The conditions resulting in the minimum flow were relieved by a series of wet years, during which the tremendous underground reservoir from which the river takes its source was greatly replenished. A low flow may again be occasioned by another series of dry years before the Owens River water can be made available, and such a flow would take place when the maximum demands are made on the system. A large amount of flood water passes through the narrow canyon of the river at the pumping station, however, during the rainy season and is dissipated in the sands below the city, even in the dryest year. A considerable portion of this flow can be conserved in the Silver Lake reservoir and made available for use during the summer, when the supply from the river is too low.

The reduction in the per capita consumption since the water-works system came under the control of the city is one of the most remarkable features of the municipal administration. In 1902 the per capita consumption was 300 gal. per day. By the gradual introduction of meters, by the replacement of defective house plumbing required by the increase of pressure on certain sections of the distribution system and by a careful system of inspection, the daily consumption has been reduced to 135 gal. per capita during the past year. This great reduction is all the more noteworthy in light of the fact that the water necessary to irrigate the extensive lawns and gardens of the city is supplied from the domestic system, and that for from five to seven months during the summer no rainfall occurs.

About 40 per cent. of the service taps are now metered, including all of the extravagant users of water, and additional meters are being placed as rapidly as possible. It is believed the consumption can scarcely be reduced to less than 130 gal. per capita, even when the system is practically all metered, but this reduced amount, as compared with the former consumption, and the reservoir capacity that has been made available tend to relieve the situation until such time as the aqueduct is capable of delivering water.



Reservoir Roof Trusses and Girders, Los Angeles Water Supply System.

The cost of the extensive improvements which have been made to the existing system since the city obtained control, with the exception of the Crystal Lake dam, has been met from the earnings of the system. Meanwhile, the flat rate for water has been reduced 10 per cent., while the meter rate has been reduced 50 per cent., the present meter rate being 7 cents per 100 cu. ft. to all consumers.

The affairs of the water department of Los Angeles are directed by a separate board of commissioners, consisting of Messrs. John J. Fay, Jr., president; John R. Mathews, M. H. Sherman, John H. Norton and Fred L. Baker. The construction, maintenance and operation of the system are under the direction of Mr. Wm. Mullholland, superintendent of the department, who has been connected with the system for over thirty-one years. Mr. Fred J. Fischer is chief mechanical engineer, Mr. Tom Brooks, superintendent of construction, and Mr. George Read, superintendent of the meter department.

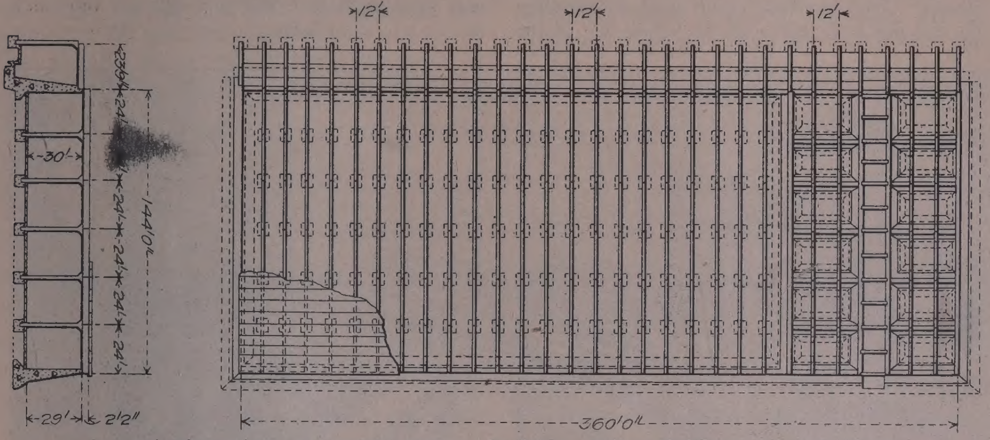
Concrete Shop Construction with Separately Molded Members.

For something over a year, the Edison Portland Cement Co. has been constructing mill buildings by casting the members separately and erecting them after they became sufficiently hard to handle. Two kiln buildings and a clinker storage building have been built in this manner, and a cement storage building is now being erected in accordance with the same system modified to utilize improvements suggested by past experience. At the recent convention of the National Association of Cement Users, Mr. W. H. Mason, general superintendent of the company, described the work on the cement storage building, with the aid of lantern pictures, and from this information the following notes have been prepared.

This building, of which a general plan and end elevation are shown, is designed to hold 350,000 bbls. of cement. Its overall dimensions are 144 x 360 ft. by 30 ft. high. On account of the enormous pressure of cement when stored in bulk, the side walls were made in place by the usual method, and are 7 ft. thick at the ground line. One end of the building contains twelve bins, the walls of which were also made in place. The columns, girders, and roof slabs were cast about half a mile away and brought to the building on railroad cars for erection. The roof, which has an area of over 50,000 sq. ft., is made of 12 x 6 ft. concrete slabs 4 in. thick. These are supported by concrete girders, which, in turn, are carried by the columns. There is also an additional row of girders and columns on one side of the building for the purpose of carrying the conveyors which deliver cement into the building. In the completed building, there is a total of 141 columns, 187 girders, and 720 roof slabs.

In preparing to cast the members a ½-yd. Ransome concrete mixer was set up at a place convenient for getting stone, and then a spur track was run to it which was connected to the main railroad line by a switch. On each side of the spur track, which was on practically level ground, beds were leveled off and 4 in. of cinder put on them. The cinder was wet down and rammed, and concrete 4 to 5 in. thick was placed on it, its surface being leveled off and smoothed with a trowel. These casting floors or beds were made of various sizes to suit the members which were to be made on them; the usual size was 10 x 50 ft. It was estimated that these casting floors would be much cheaper than floors made of lumber, and this estimate was borne out by the cost records, which show the beds to cost 4 cents per square foot. This cost Mr. Mason compares with that of some slabs which were cast in Chicago for street crossings for the Chicago, Burlington & Quincy Railway, in which work the lumber alone for the floors cost 20 cents per square foot, he stated.

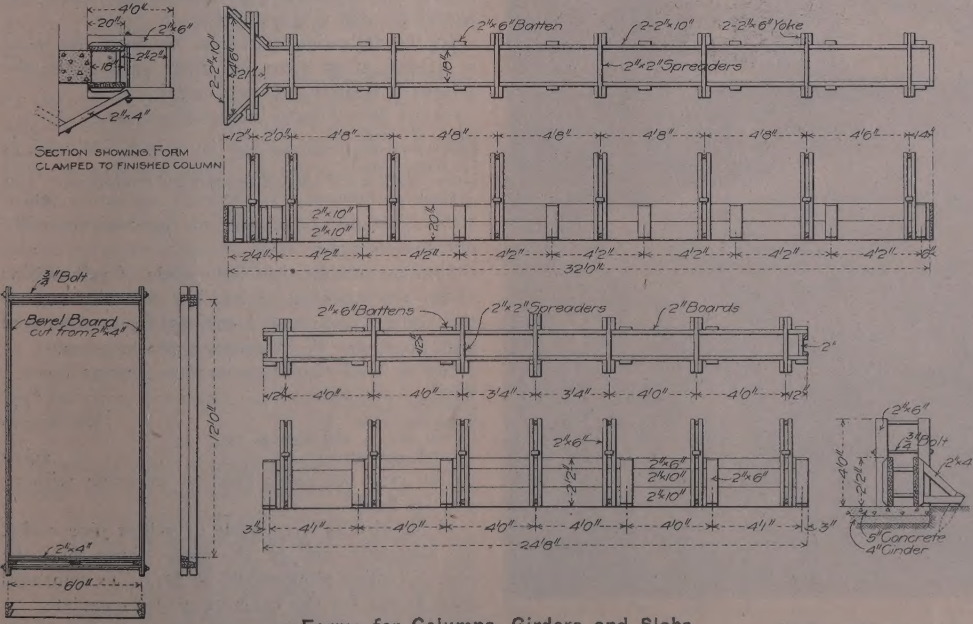
The style of the forms used for the columns, girders and roof slabs is shown in an accompanying illustration. The column forms were made of 2-in. lumber planed on one side and two edges. They were made 20 in. deep, 2 in. deeper than the columns, so that in setting one up on top of a column previously cast, it would clamp 2 in. on the lower column, which would facilitate setting the forms. The yokes used were 2 x 6 in., as shown, with a spreader at the top and a ¾-in. bolt through just above the form. Seven column forms were made, and with these 141 columns were cast. The forms were in good condition at the end of the work, and could easily be used for as many more columns.



General Dimensions of Cement Storage Building, Edison Portland Cement Works.

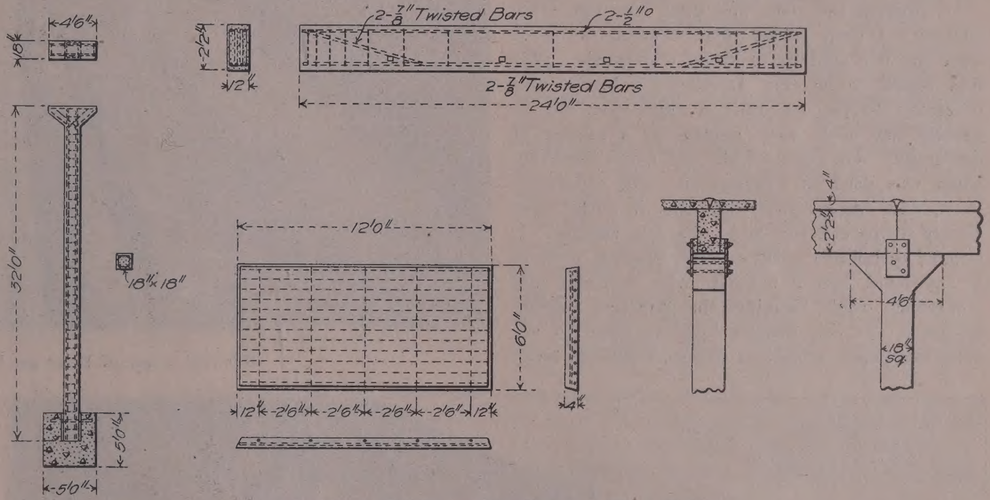
The girder forms are built just like the column forms, and used in the same manner. Only five girder forms were made, and with these 187 girders were cast. Frequently girders were cast with no forms of lumber, and sometimes only one-half of a form was used.

The roof slab forms are somewhat different; these are made 8 in. deep, with the upper half identical with the lower half, except that it is offset 4 in. endways. The upper 4 in. is the form proper, while the lower 4 in. is used to clamp on the slab below. The offset is made to permit lifting the slabs after they are cast. The bevel strips are put on to give the edges of the slab a taper, so as to have a place for calking to make a weather-proof joint. Twenty-eight of these forms were made, and 720 roof slabs have already been cast; as the company has adopted a 6 x 12 ft. by 4-in. roof slab as a standard, the forms will probably be used for many more castings.



Forms for Columns, Girders and Slabs.

The details of the columns, girders, and roof slabs, and also the method of making the joints where the various parts are assembled, are shown in an accompanying illustration.



Details of Columns, Girders and Roof Slabs.

The columns are 32 ft. long and 18 in. square, with two kneebraces extending 18 in. at the top. The reinforcing consists of four ⅞-in. high carbon twisted steel rods with hoops of ¼-in. steel spaced 9 in. apart on centers. The foundations for each column were 5-ft. cubes made in place with the socket 20 in. square. The depth of these sockets was left low, and after all foundations were in the bottom was grouted up to the proper height. The slope on the roof, which has a pitch of 1 ft. in 150 ft., was made in this way; all columns were made the same length. The top of the foundation was reinforced to prevent breaking out. Two pieces of pipe were cast in the top of the columns for bolting on the plates which hold the column and girder together.

The girder is of straight rectangular form 24 ft. long, 26 in. deep and 12 in. thick, reinforced by four ⅞-in. high carbon twisted steel rods with hoops, and two small rounds in the top, as shown. Pipes were cast in the ends for fastening to the columns, and 2 a 24-in. wood blocks were set in at intervals for the purpose of connecting electric wires.

The roof slabs, as before stated, are 6 x 12 ft. by 4 in. thick, reinforced with twelve ⅜-in. square rods in the line of their supports. Five ⅜ in. square rods run crossways to hold the slab together in handling. The edges are beveled ⅜ in., making an opening of ¾ in. at the top when the roof slabs are in place.

In assembling the building, the column is first set in the socket, which has 1 in. clearance all around. It is plumbed, and then wooden wedges are driven in to hold it. A grout of one part of cement and three parts of sand is then poured in; as soon as this sets sufficiently the wedges are removed and the space filled with more grout.

The tops of the columns and the bottom of the girders, where they rest on the columns are soaked with water for some hours before the girders are set in place. This is done by tying burlap on these parts and soaking it. Then a 1:3 mortar is put on top of columns, and the girders set in place, which squeezes out the mortar, making a perfect bed for itself. The roof slabs are then placed on the girders with a mortar joint the same as between the column and girder.

It has been found that by using a very wet mixture it is not necessary to water-proof the slabs in any way; they show a little dampness for only a short while, and the pores soon seal up, which leaves only the joint between the roof slabs to be taken care of. This is done by first calking the taper crack with oakum for a depth of about 2 in.; then the edges are cleaned and painted, and the remaining 2 in. is filled with a composition made of one part of coal tar and two parts of cement, boiled together and applied while hot. This has proved to be entirely satisfactory, and is a very inexpensive filling.

In addition to the mortar joint between the column and girder, a ½-in steel plate is bolted on, which connects the two girders to the columns. This is considered unnecessary, but has been put on as an additional precaution. The roof slabs are not fastened in any way, dependence being placed entirely upon the mortar joint and their weight to keep them in place.

In carrying on the work advantage was taken of all local conditions likely to reduce the cost. For example, the concrete mixer was placed under a conveyor which carries crushed cement rock to the stock house. This rock, straight from the crusher, was used for concrete, and was discharged into the bins of the mixer plant through a chute running down from the conveyor. When the rock in the bin was low a scraper was placed on the belt conveyor and enough stone was scraped off to fill the bin. There is a small hopper under the bins and over the concrete mixer which holds just one batch of stone and cement. The mixer is on an elevated platform, and its contents are discharged directly into the 3-yd. cars which deliver the material to the casting beds.

A general view of the yard and casting floors is shown in one of the engravings. In the foreground is shown a row of columns with girders cast between them, and the reinforcement for other girders which are to be cast, using the sides of other girders for forms. The reinforcement for columns was made up and wired together, ready to be set in the forms, by Italian labor, by piece-work at a rate of 85 cents each.

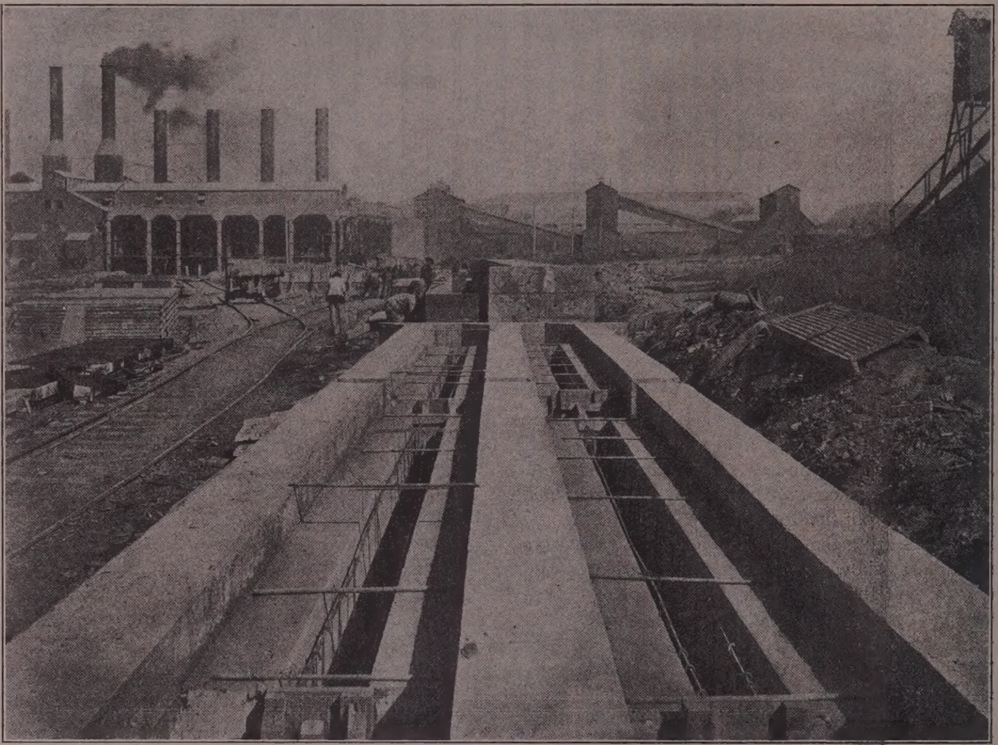
To prevent the slabs and other castings from sticking to each other, their abutting surfaces were given a coat of ordinary whitewash. This was found to be very satisfactory, but it was necessary to put on quite a thick coat of it; usually two coats were applied as a matter of precaution. On some of the old work sheathing paper was used as a separator. The objections to it, Mr. Mason said, are that it sticks very closely to the concrete and is hard to remove. It is hard to hold in position while casting, if there is any wind, and it expands with moisture and sometimes folds, leaving the concrete casting irregular. It was proposed at one time to use parafined paper, which, of course, would do away with the spotted appearance of the castings, but this was not objectionable, as everything around a cement mill soon comes to the same color.

In filling the slab forms, a few shovelfuls of concrete are first thrown in the mold and spread so as to have a thickness of about ¾ in. Then the steel rods are laid on this, and the concrete is discharged from a gate in the car down a chute into the mold; the concrete is made very wet and will flow readily. Slabs that are cast one day are whitewashed the following morning and the forms raised; in the afternoon another slab is cast on top of the first.

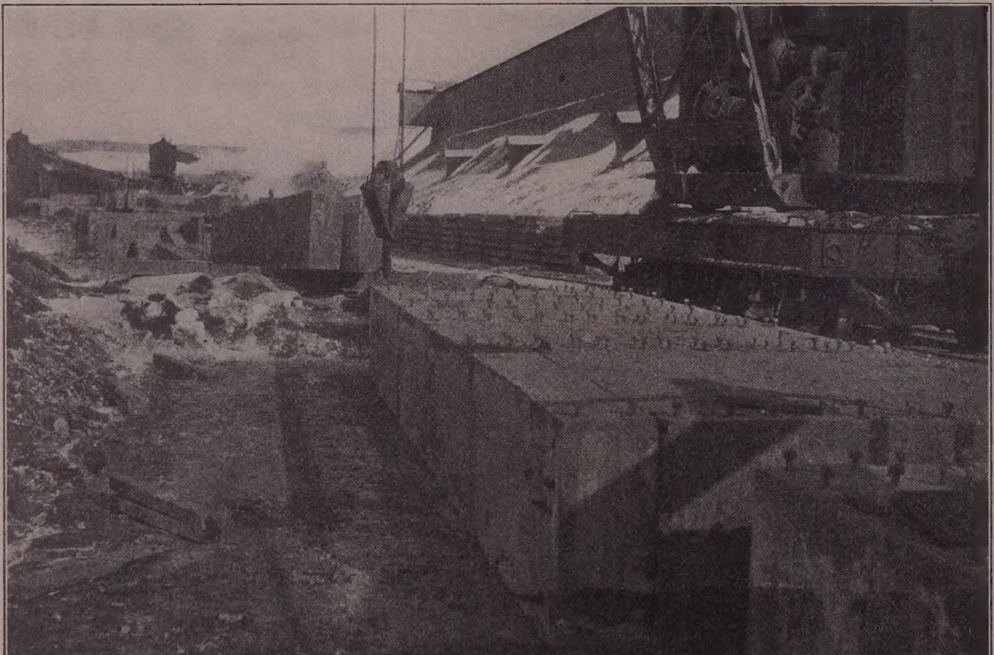
One of the accompanying pictures is a view of a bed of girders, which go on the outside of building and have bolts for fastening the machinery. The traveling crane used in handling the cast pieces is in the act of lifting one of the girders by means of the hole cast in one end. The columns and girders were erected by means of the locomotive crane.

The work on the 1048 cast members was started Sept. 25, 1907, and completed Nov. 23, 1907; that is, it was all done in two months. Some preliminary work had been done previously, such as setting up the concrete mixer, laying the railroad track, and making a few casting floors to start on. The average number of men employed during this time was 23. Eleven of these were classed as carpenters and foremen, whose average rate was 24 cents per hour, and twelve were classed as laborers, whose average rate was 15 cents per hour.

The lumber used for making the 1048 pieces was 7000 board feet, which, at $27 per thousand, makes a total of $189.



General View of Beds on Which Members Were Cast.



View of a Bed on Which Girders Were Cast.

The total amount of steel used was 201,400 lbs., the average price of which delivered at the cement mill was 2.03 cents, or a total cost of $4,088.

The mixture used was 1 to 6, using the run of crusher stone straight without sand. The stone would all pass a ¾-in. screen.

In the following statement of costs the stone is figured at 60 cents per cubic yard, while the cement is figured at $1 per barrel.

Cost of Each Column Complete on Casting Floor.

Cost of steel	$8.57
Cost of material for concrete	5.48
Carpenter labor	4.27
Labor, making and placing concrete and reinforcing	1.95
Total per column	$19.27

The cost per cubic yard of the concrete without steel is $3.64.

If these columns had been made of yellow pine at $35 per thousand, and of the same dimensions, the lumber alone would cost $33.60, as compared with $19,27 for the complete concrete column.

Cost of Each Girder Complete on Casting Floor.

Steel	$5.53
Concrete material	3.51
Carpenter labor	2.26
Labor, mixing and placing, etc	1.34
Total per girder	$12.64

The cost per cubic yard of concrete without steel is $4.20.

If the girders were made of yellow pine at $35 per thousand, and of the some dimensions, the cost of lumber alone would be $21.84, as compared with $12.64 for the concrete girder complete.

Cost of Each Roof Slab Complete on Casting Floor.

Steel	$1.69
Concrete material	1.85
Carpenter labor	.423
Labor, mixing and placing concrete, whitewashing, smoothing tops, etc	.405
Total per slab	$4.37

There are 72 sq. ft. in each slab, therefore the cost per square foot is 6.07 cents, or $6.07 per 100 sq. ft.

The usual practice of this company on roofs of galvanized iron is to use No. 18 corrugated iron.

Weight per square with usual lap is 292 lb., at $3.05 per 100 lb (for the iron alone)	$8.92
Paint for three coats	.61
Labor painting	.36
Labor putting on	2.75
Total per square in place	$12.64

The actual figures for laying the concrete slabs were not available when Mr. Mason read his paper, but he had a bid from a responsible party to erect the entire roof, columns, and girders, for $1,932. Mr. Mason believes his company can do it at less cost by day labor, but assuming that figure as the cost, and allowing the erection of the slabs to be one-half of the whole work, as there are 518 squares in the building, the cost of erection per square is $1.86, as the cost of the slabs per square is $6.07, the total cost in place is $7.93.

To sum up the cost of the concrete roof slabs in place per square is $7.93, while the cost of No. 18 corrugated iron in place per square is $12.64.

One of the roof slabs was tested to destruction; it failed at 7700 lb. center load, with 12-ft. span. This is considered to give an ample factor of safety for a roof.

There have been the following criticisms of this class of construction: 1, The joint between the members is not sufficiently strong. 2, The machinery necessary to hoist them in place is expensive.

In reply to the first, Mr. Mason cited a case that occurred in setting up this building. Two of the girders were set on the columns 4 in. out of line. This was discovered after they had been in place three days, and an attempt was made to take them up. The crane, which has a lifting capacity of 16 tons, could not move them, and it was necessary to separate them by iron wedges driven in the joint. If all the joints are as sound as these after being set only three days, Mr. Mason is satisfied that they will answer every purpose.

In reply to the second criticism, Mr. Mason stated that his company used locomotive cranes and a railroad for handling the pieces because it had these facilities on hand, and it was more economical to do the work in this manner. However, they are not at all necessary, as in many cases the floor of the building itself could be used for a casting floor, and the members raised by an ordinary derrick or gin pole, for the heaviest piece weighed less than six tons, and it does not take a very large gin pole or derrick to lift six tons.

The company has not as yet had an occasion to use slabs for the sides of a building, but it sees no reason why they could not be used as readily for siding as for roofing, if provision were made for bolting them to the columns.

One advantage claimed for this method of construction is that the concrete and reinforcing can be properly inspected while it is being put in, as this can be readily done while working on the ground, but can not be so readily done while working on high stagings. Each member can also be thoroughly inspected as it is removed from the casting floor, and in case any of the members are defective, they can be discarded and others substituted.

Transportation Facilities on the New York Subway can be increased, according to a report made to the Public Service Commission by Mr. B. J. Arnold, by adding on each side of every car two additional doors. At each end there will thus be four doors, and the two on each side will be separated just enough to permit the location of seats for two passengers between them. The doors nearer the ends, which are the present doors, are to serve for entrance solely, while the others are for exit. This arrangement of doors is recommended by Mr. Arnold on the ground that it will reduce greatly the train stops at stations.

Sewage Purification in Ohio.

Last week there was printed in this journal a review of the investigations conducted by the Ohio State Board of Health to determine the actual conditions at the works for purifying water supplies in that State. In the preliminary report on the investigations, made by Mr. R. Winthrop Pratt, chief engineer of the board, from which the information in the article was derived, there was also a summary of the conditions at the sewage-purification plants of the State, and the following notes give the substance of that part of the report. In making the investigations Messrs. Philip Burgess and A. Elliott Kimberly were engaged as special assistant engineers to examine the plants for the purification of water and sewage respectively.

The special assistant engineers have made continuously a series of examinations and inspections of all water and sewage purification plants in this state, each examination covering a period of from one to five days or more. During each examination there were made the chemical, bacterial and physical analyses necessary to determine the efficiency of the plants, and complete records were kept of all features relating to operation cost, and general efficiency. All information relating to the construction of the plants has been studied and recorded, and to supplement the data obtained by the Board's engineers, records of certain features of operation have been kept with considerable accuracy at a large number of the plants by the local managers.

The dry weather flow of the rivers and streams in Ohio is usually entirely too small to dilute inoffensively the sewage which is discharged into them from cities, villages and public institutions, Mr. Pratt states. Sewage purification is, therefore, necessary if the farmers and other riparian owners living down stream are to be protected. Furthermore, the dry weather flow of the streams seems to be decreasing from year to year, and this makes the problem of sewage purification more and more important.

Geological conditions in Ohio are such that sand or gravel in sufficient quantities, and suitably located for constructing intermittent sand filtration areas, are rarely found. In regard to broad irrigation, the price of land is too high in localities near the cities, and, furthermore, the rainfall in this State is such that the ground has little capacity for absorbing sewage. As regards the larger municipalities, at least, those processes which require the minimum area seem most desirable. At first there were built chemical precipitation works effecting only partly purification; but for the last six or seven years it has been the usual practice to use septic tanks as a preliminary process in connection with broken stone, coke, cinder, or sand filters.

The first sewage purification plant in Ohio was the chemical precipitation plant built at Canton in 1893. Five years later seven plants were in use by municipalities and public institutions. Up to the present time 46 plants have been built or are under construction in the State; 23 are municipal and 23 institutional.

When all of the 46 plants included in the above table are in operation, the total population tributary to sewage purification plants in Ohio will be nearly 270,000. This is twelve per cent. of the urban population and seven per cent. of the entire population of the State. It will be noted that these percentages are small when compared to that of the urban population supplied with filtered water. One of the principal reasons why such a comparatively small number of persons is served by sewage plants is because the larger cities established their main sewer outlets before the State Board of Health was given jurisdiction over proposed sewerage plans, and hence the cities were free to locate the sewer outlets as they chose. Furthermore, the larger cities are generally situated near rivers and lakes of such size as to afford considerable dilution for the sewage discharged.

Proposed plans for some fifty more plants, all municipal, have been approved by the State Board of Health, and it is expected that the construction of these will be commenced in the near future. With the completion of these plants stream pollution in Ohio will be greatly checked though by no means eliminated. With the later proposed plants, as well as with the plants under construction, septic tanks and sprinkling filters have been adopted largely.

During the investigation, examinations and inspections have been made of 35 sewage plants which have been in operation, each plant having been visited one to eight times and the larger plants at least seven times. Each examination has usually consisted of continuous observations, covering periods of from 24 to 72 hours, of the principle features of operation of the plant, such as quantity of sewage treated, temperature observations, sludge measurements and the efficiency of purification as shown by chemical, bacterial and physical analyses of representative samples of the sewage and effluent. During these examinations there has been used additional assistance from the regular force of the State Board of Health, as well as from local sources. When an extended examination was not warranted, the plant was given simply a thorough inspection. After each visit the local officials were advised in regard to making necessary improvements or changes. At one or two places the attendants have been taught to make simple chemical and physical tests of the effluent, in order to determine daily the efficiency of purification.

At the end of the investigation 22 plants were classed as satisfactory; that is to say, they are accomplishing the purpose for which they were designed, by preventing a nuisance in the stream receiving the treated sewage. Thirteen plants were not satisfactory. Few if any plants gave cause for complaint by reason of creating offensive odors or local nuisances. As there have as yet been placed in operation no plants which are intended to effect high bacterial purification, or to disinfect the sewage, efficiency from this standpoint is not considered.

Ignorance and carelessness in operation, and even absolute neglect, together with outgrown plants, are responsible for most of the failures, Mr. Pratt states. In some cases the plants have been built on wrong principles, but usually they are sufficiently correct in design to permit of obtaining good results if properly managed and if not worked beyond their capacity. The failure on the part of operators to understand the principles of sewage purification and the consequent failure to manage the plant properly is largely due to the fact that the engineer who designs and builds the plant is not retained long enough to test it or to instruct the future operator as to its workings. In some cases there has been left by the builder the erroneous idea that the plant is practically automatic. Little thought is given to the necessity for increasing the capacity of the plant as the sewage changes in character or increases in volume. Frequently, lack of provision for future development of the original design has made an enlarged plant difficult and expensive to secure.

Viewing the matter solely from the standpoint of preventing offensive pollution of the streams of the State, that is, from the standpoint of producing a non-putrescible effluent, the investigation has shown that intermittent filtration through sand or other fine material, such as crushed coke or cinders, is the most satisfactory method. Of the 22 plants which at the end of the investigation were producing a satisfactory effluent, 17 employ this type of filtration. From another standpoint, out of 19 sand filtration plants (using this as a general term for filters of fine material), 17 were satisfactory; of 16 plants of other types, such as contact filters, miscellaneous coarse grain filters, septic tanks alone, and chemical precipitation, only five were satisfactory. It is true that the 17 fine-grain plants include several small institutional plants, but the sewage from these is generally quite as difficult to treat, at a given rate, as is municipal sewage.

The fine-grain filters have in many cases purified the sewage considerably beyond the non-putrescible limit and to a degree which could not be expected with any of the other methods. On the other hand, two or three of the contact filter plants have produced effluents which have entirely fulfilled the requirements of local conditions and which have been sufficiently satisfactory. While, therefore, filtration through sand or other fine material has served to better protect the streams of Ohio and gives better bacterial purification than other methods, yet where the cost places this method beyond the means of the municipality (as is usually the case with the larger plants), and where a high degree of purification is not necessary, coarse-grain filters, if amply and correctly designed, may be installed with safety.

In regard to odors from sewage plants, considered independently from the character of the effluent produced, the investigations have shown that this feature has not been an important one and that with a well-designed plant it can be controlled by intelligent management. The degree of offensiveness of odors and the distance penetrated by them are largely affected by the condition of the atmosphere. Odors more or less objectionable may arise from scum or from freshly deposited sludge, when the latter is exposed to the air, as is done when septic or settling tanks are cleaned. This usually affords no cause for complaint, however. Odors may be caused by the aeration of septic sewage, if the latter has been retained too long in the tanks. No odors need be caused from the filters, whether they be of sand or other material, if the sewage is applied intermittently in suitably proportioned doses and the surfaces of the filters are kept reasonably clean.

At the beginning of the investigation some two-thirds of the sewage purification plants, including most of the larger ones, were found to be defective in regard to features of operation or design, or both. Municipal officials were found to have little interest in sewage purification, because it is a matter which benefits their neighbors downstream rather than themselves. Furthermore, most plants have been built by reason of complaints from people living outside of the community, and under protest from the local officials. This has created a desire to build just as small and cheap a plant as possible, to have it operated by unskilled attendants, and to allow it to become outgrown. The importance and interest given to the sewage purification plant by local officials were found, for the above reasons, to be much less than the interests given to water purification plants by such officials. Requests by the Board, however, supplemented by personal visits by its engineers, have resulted frequently, though not invariably, in arousing the interest of local officials and establishing in them a feeling of greater responsibility. As a result, 11 plants, or one-half of those unsatisfactory at the beginning, were, during the investigation, made efficient, or were considerably improved.

The following are some of the most important features relating to the design and consequently to the efficiency of sewage purification plants, which have been discovered or emphasized by the special investigation.

Screens afford a simple means for efficiently and economically effecting the removal from the sewage of a certain amount of the coarser suspended matter, and they should be provided as a first step in all sewage purification schemes. The mesh of the screen should be made to fit the local conditions, giving due consideration to the fact that very thorough screening means increased expense, and that this may overbalance the cost of removing the suspended matters in the subsequent processses.

Chemical precipitation plants and sedimentation basins, especially the former, have been shown to be unnecessarily expensive on account of the cost of chemicals with the former, and the cost of sludge disposal with both. Septic tanks afford usually a simple means for not only clarifying the sewage, but, to a large extent, for disposing of the sludge. They may be used, therefore, where no extraordinary conditions obtain, as a means of preparatory treatment.

The tanks should not be too large, as long retention, except in case of weak sewages, produces foul effluents. Any putrefactive change in the effluent as it passes through the tank is a disadvantage, not only on account of the odors, but because its final treatment is made more difficult. The principal septic tanks now in use in Ohio have been designed on a basis of holding 24 hours' flow. Fortunately, the sewage at these places is quite weak and has not been rendered foul by being held so long. With sewages of ordinary strength, it is believed that tanks holding 8 to 12 hours' flow are large enough.

At several places the sludge from the bottom of the tank is from time to time heaved to the surface in large masses, which when not held back by thorough baffling, pass to the filters with the tank effluent and tend to cause objectionable clogging. This action is especially violent in the spring and summer when the temperature is most favorable to bacterial life and the formation of gas. Tanks should always be divided into units, so that when one unit acts in the above manner it can be cut out of service.

Although the sludge disposal problem, as discussed above, is greatly reduced by the use of septic tanks, it is nevertheless necessary to provide some means of sludge disposal with all plants. Usually a rough filter or a leveled area of ground will be sufficient. The length of periods between necessary cleanings of a tank varies, as shown by the investigation, from a few months to four years or more, depending on the character of the sewage and size and design of tank.

Regarding the necessity for covering septic tanks, it may be said no offensive odors from the contents of the tanks, under normal operation, will travel more than a few hundred feet; but that if the tanks are drained down and expose undigested sludge, offensive odors will be created. Scum in sufficient quantities will also cause odors. Covers would not entirely prevent odors, as the sludge and scum would have to be handled, in any case, to a certain extent outside the tank. Covers have, however, the advantage, especially in the colder part of the State, of causing a more even temperature in the tank throughout the year; and where the sewage plant is exposed to the view of a considerable number of persons, as near a public highway or park, a much better and cleaner appearance is given to the entire sewage plant by covering the tanks.

In the final treatment more than in any other feature of the process must be considered the degree to which the sewage should be purified. The area available for filters as well as the available head for operation must also be given great weight in this connection.

Intermittent filtration through sand or other fine material, such as crushed coke or cinders, affords, aside from the disinfection processes, a method for producing the effluent of greatest purity. This method is, however, on account of the absence of suitable local sand, generally too expensive to be considered by the larger places It has a valuable and practical field, where a high degree of purification is required, as in filters which treat as a finishing process the effluent from coarse-grain filters. This process is also suitable for public institutions.

The rates of filtration have been found to vary with the strength and character of the sewage, with the size of filtering material, and with the preliminary treatment. In large plants the question of operating expenses in cleaning the filters must be given due consideration in deciding upon the rates to be used. It is not believed that sewage treated by septic tanks has any advantage over that treated by plain sedimentation, as regards the rates possible with subsequent filtration

The practical rates of filtration with the intermittent or fine-grain filters studied is greater in summer time than it is in winter, on account of the difficulty of removing solid matters from the surface of the filters when covered with ice. An important adjunct to this type of filter is a dosing tank. With the rates of filtration usually employed, it has been found that only with such a tank can proper distribution be obtained. Furthermore, winter operation of the filters is greatly facilitated by applying the sewage in doses.

Contact filters, of which there are two successful examples in Ohio, afford means of producing on a comparatively small area of land and with little fall an effluent which is sometimes but not always non-putrescible. Such effluents are only fit to discharge into streams having considerable dry weather flow, from which no public water supply is drawn. The studies would seem to indicate the fact that only the weaker sewages can be satisfactorily purified by this method alone. When followed by secondary treatment on filters of sand or other material, this method may be used to advantage with stronger sewage.

The automatic controlling devices, usually employed with contact filters, have at the larger plants been generally satisfactory; but those at several of the smaller plants have proved to be absolute failures. These automatic controlling devices have at one place been omitted, and the flow of sewage is changed from filter to filter by the attendant with more or less regularity.

Sprinkling filters, as shown by the results of experiments in Ohio, afford a means of producing a non-putrescible effluent upon an area considerably less than that required for contact filters, and at a correspondingly less cost. The head for operating sprinkling filters, on the other hand, is greater than that required for contact filters. The absence at the end of the investigation of any completed sprinkling filter plant in Ohio has prevented the securing at first hand of any data regarding this method.

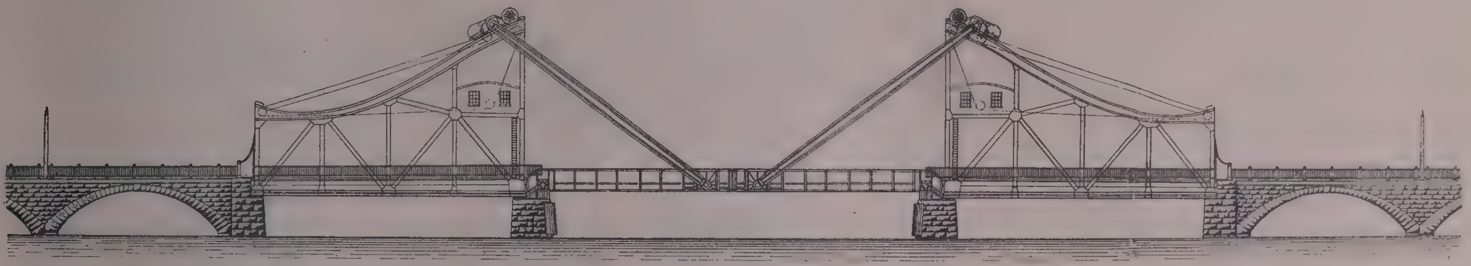
Of the plants now in operation in Ohio, the greatest in the first cost is that at Mansfield, for which $75,000 was paid; while for that at Oberlin, the least in first cost, there was paid $2,500. The average cost of construction of municipal plants based on the study of ten representative cases, is $4.17 per person tributary.

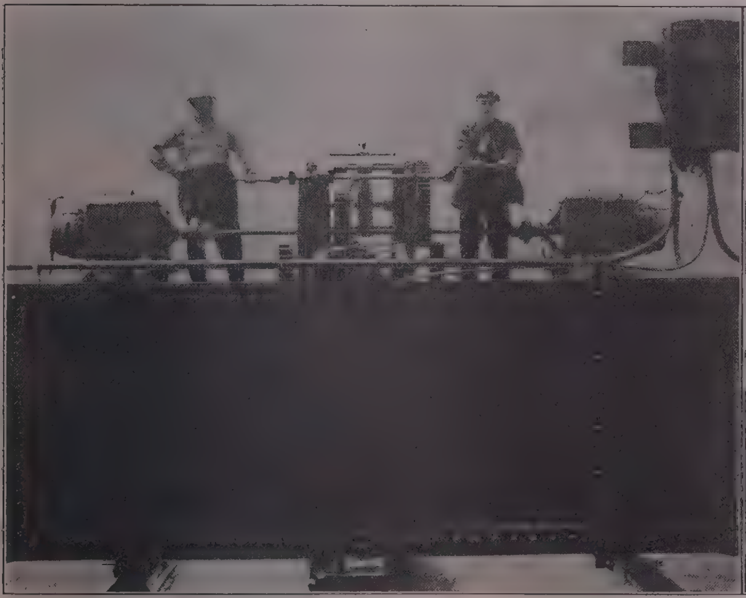
The annual cost of operation of these municipal plants ranges from 16 to 79 cents per person tributary, while the average is 47 cents. This figure includes interest charges, which in several cases equal or exceed the amount spent for actual maintenance. With institution plants the real cost of operation is very small. There are no actual interest charges, and the plants can usually be operated by the inmates or by one of the employees of the institution, who may in addition have other duties.

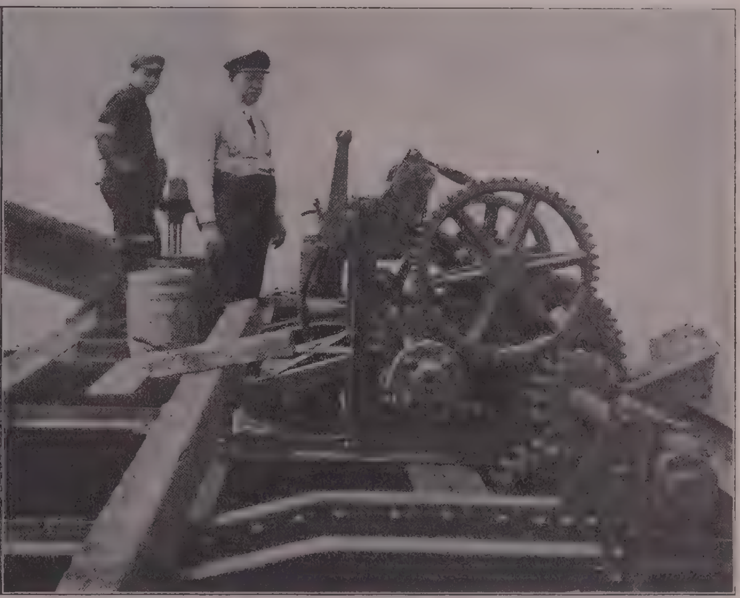
The Portland Cement Production in the United States in 1907 is reported by the U. S. Geological Survey to have amounted to approximately 48,000,000 bbl., as against 46,463,000 bbl. in 1906 and 35,247,000 bbl. in 1905.

The Bascule Bridge Between Portsmouth and Tiverton, R. I.

The so-called Rhode Island stone bridge spans the Sakonet River between the towns of Portsmouth and Tiverton, R. I. In the fall of 1904 severe storms so badly wrecked its abutments that navigation and traffic were seriously menaced. As the stream is navigable and therefore under the control of the War Department, Congress had previously made an appropriation of $40,000 for the removal of the old bridge and improving the channel at this point. The commissioners appointed by the Legislature of the State of Rhode Island decided, under advice of Mr. O. Perry Sarle, their engineer, to maintain navigation through the bridge by a bascule span. On March 30, 1905, 21 bids were opened and on one of them the contract was awarded for the bridge now practically completed, which it is estimated will involve a total cost of nearly $250,000.


Fortress Bascule Spans of Stone Bridge between Portsmouth and Tiverton, R. I.


Operating Mechanism and Counterweight Girder.


Main Operating Gear, Portsmouth-Tiverton Bridge.

It has a total length of about 1,632 ft., and includes two approaches, respectively about 581 and 439 ft. long, with earth fill between longitudinal masonry retaining walls. Between the approaches the structure is symmetrical about the center line and consists of a clear channel opening of 100 ft. spanned by two bascule leaves and two 70½-ft. steel side spans planked on each side by three 45-ft. arch spans. The roadway is graded up from both ends to the center where it has a clear height of 13 ft. above high tide. The roadway has a uniform width of 32 ft., and there is a cantilever sidewalk 5 ft. wide bracketed out on one side.

Except the three center spans the bridge is built of quarry faced masonry backed with rubble. The arches have face rings of dimension stones with cut joints and the sidewalk has a 3-in. plank floor carried on structural steel brackets. Except for the steel spans the roadway is of macadam on sand filling up to sub-grade and has a strip of granite block pavements, 2½ ft. wide, adjacent to each wheel guard. The 1:3:5 concrete is made with 2-in. broken stones or gravel and Lehigh Portland cement. The piers are 8 ft. wide between the arches and 10½ ft. wide on top at the ends of the bascule span and were built by divers to a depth of 30 ft. below low tide and rest on pile foundations.

The medium steel superstructure has a total weight of about 860,000 lb., and is proportioned for a live load of 100 lb. per square foot of roadway and sidewalk in addition to an 80,000-lb. electric car with four axles 6 ft. apart or a 14,500-lb. steam road roller with axles 4½ ft. long and 12 ft. apart. The counterweights carried by the side spans are also considered as live loads. The top lateral bracing is proportioned for 150 lb. dead and 150 lb. live load and the bottom lateral bracing 150 lb. dead load per lineal foot. Provision is made for expansion due to temperature changes of 150° Fahr.

The most interesting feature of the design is the bascule span with a 100-ft. clear opening provided by two independent counter-balanced leaves. The floor of each leaf is carried by a pair of through plate girders 75 in. deep and 58 ft. long over all in the planes of the side span trusses 34 ft. 7 in. apart on centers. The girders are pivoted to riveted pedestals at the shore ends and at the other ends are supported by inclined operating struts 76 ft. long on centers. The lower ends of these struts are pivoted to the girders and the upper ends are pivoted to special four-wheel trucks running on overhead tracks and carrying the counterweights.

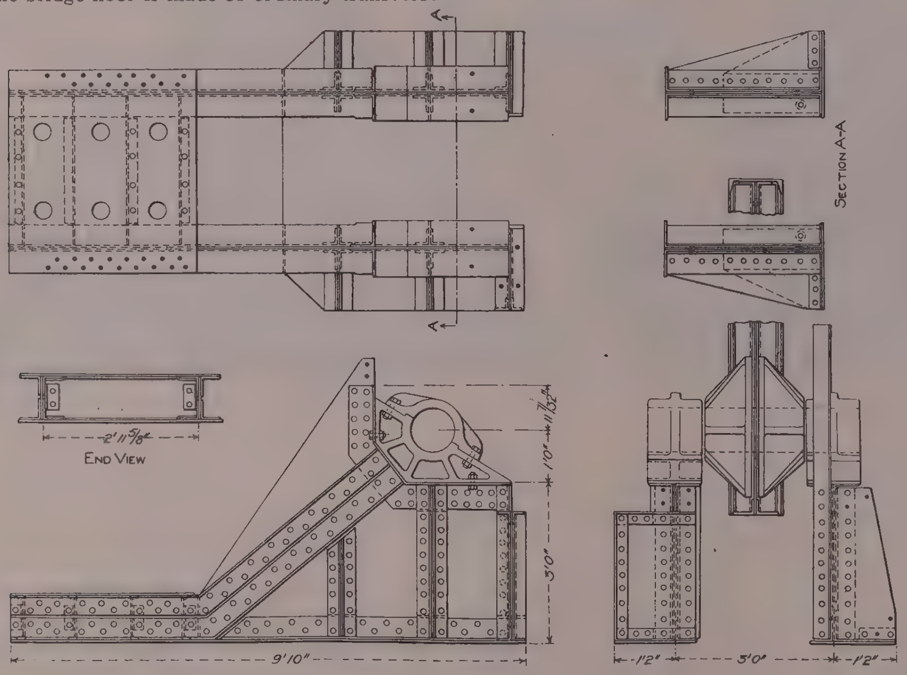
The curves of the tracks and the amount of counterweights are proportioned to balance the varying moments of the bascule leaves in their successive position and maintain the structure in equilibrium opened or closed or at any intermediate points. The power is applied directly to the wheels of the counterweight truck making them locomotive up and down their track and eliminating the necessity for wire rope transmission, long shafts and complicated mechanism. The bascule is operated by duplicate Northern Electrical Co.'s slow-speed, crane motors arranged to be used singly or in conjunction and each of them able to open or close the span within two minutes. They are operated by a 500-volt current and hand power is provided for use in emergency.

The side span trusses are long enough to prevent unreasonable obstruction of the water-way by their piers and not only support the roadway but carry on their top chords the counterweight tracks, thus avoiding the use of pits and maintaining all parts of the moving structure and mechanism where they are easily accessible with reasonable clearance above roadway level. The trusses are of ordinary riveted construction with stiff members throughout. They have top and bottom lateral systems of X-braced angles, a plate girder portal at the shore end with a vertical clearance of 15 ft. above the roadway and two panels of transverse sway-bracing at the river end. The bottom chords and vertical members have I-shaped cross-sections made with a web plate and four flange angles and the inclined members have rectangular cross sections made with rolled or built channels having their flanges turned inward and latticed. The special top chord has a rectangular trough-shaped cross section made with two vertical web plates 18 in. apart, four flange angles and one 26 x ¾-in. top cover plate reinforced by a 12-in. 20½-lb. channel. The lower flange of the top chord is straight but the web plates have varying depths and the upper edges of the top flange are curved to correspond to the required curve of the counterweight track. The web plates are field spliced at panel points.

The bascule girders are of ordinary construction with ⅜-in. web plates 75 in. deep, spliced at the center of the span and full length 5 x 3½ x 9/16-in. flange angles. The top flange is reinforced by a 12-in. 30-lb. channel with the web horizontal and bent around the shore end of the girder to the bottom flange to a curve of 4 ft. 8 in. radius. The web is reinforced by intermediate pairs of vertical stiffener angles 63 in. apart and at the ends has double cover plates and pairs of heavy castings to give extended bearing for pivots. The shore end pivot about which the girder revolves is bored for a 10-in. pin with a bearing 22 in. long. At the outer end of the girders the pin connected with the operating strut is 13 in. in diameter and has a bearing 27 in. long. The extremities of the girder differ slightly on the opposite sides of the channel on account of the connections provided for the latch.

Instead of moving longitudinally in the plane of the bascule floor, like most latches, this latch revolves a few degrees from the vertical in a vertical plane parallel to the axis of the bridge and is pivoted at the lower end to the web of the main girder. It is L-shaped in elevation with a very short horizontal leg at the upper end which engages a rectangular hole in a heavy face plate perpendicular to the web of the opposite girder, very much like the spring latch operated by an ordinary door knob. The latch is made up of three thicknesses of steel plate 3 in. wide and 4 ft. long riveted together and seated in a notch slotted out of the ends of the web of the main girder between the top and bottom flange angles. It is operated by a pair of 2 x ½-in. offset links, one on each side of the girder web, which are pivoted to the operating lever close to the inner face of the girder web and parallel with it. The pivot passes through a quadrant slot in the girder web; the operating lever has the upper end guided by a quadrant bar and is provided there with a handle with which it is turned by the bridge tender, no automatic device being provided for opening and closing the latch.

Bascule Span and Counterweight, Portsmouth-Tiverton Bridge.



Pedestal for Bascule Pivot.

The bridge floor is made of ordinary transverse planks carried by plate girder stringers and floorbeams and at the shore end of the bascule leaf has a transverse joint with the fixed deck of the approach span. The joint is double so that the upper part of the bascule floors somewhat overlaps the fixed floor with a clearance of about ½ in., and the adjacent angle at the upper corner of the double floor plank is protected by a bed plate, ½ in. thick.

The operating cars, one on each approach span, run on the cruved top chord tracks and are directly connected to the operating strut for the main girders of the bascule leaves. Each car carries the counterweight and the operating machinery and is provided with hand gear by which either bascule may be independently opened or closed in about two minutes. The car is I-shaped in plan and has a total length of about 40 ft. over all transverse to the bridge axis. The car body mainly consists of a pair of horizontal plate girders 60 in. deep and about 34 ft. 3 in. long and 3 ft. apart on centers which carry the counterweight and machinery and are web-connected at the ends to the four-wheel trucks. The latter are 15 ft. 4 in. long in a direction at right angles to the main girders and are heavy plate girders 3½ ft. deep in the center with drop ends suspended from each axle of the wheels by eight 2-in. vertical bolts passing through the journal boxes.

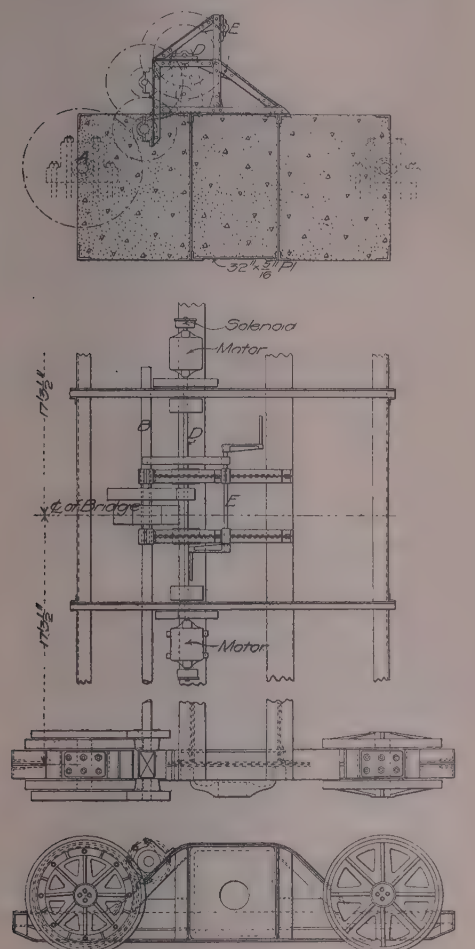
At the center of each truck girder a heavy cast-iron housing about 39 in. square is securely bolted to both flanges and to vertical web stiffener angles and provides bearings for a horizontal pin 13 in. in diameter and about 4 ft. long which forms the pivot for the upper end of the operating strut. The casting is offset far enough from the base of the girder to carry the strut clear of the flanges of the members to which it is connected and of the truck and has double pin bearings reducing the moment of the pin which also takes bearings in the web of the truck girder which serves as an anchorage for the projecting end. Each truck has four wheels 50¼ in. in diameter with 7¼-in. flat faces which engage the track plates on each side of the 12-in. channel riveted to the top chord of the approach spans, so that its vertical flanges serve as guides for the wheels. Gear wheels are bolted to the outer faces of the two bearing wheels at one end of each truck and are driven by pinions on the main shaft.

The bottom flanges of the main girders in the operating car are connected by horizontal plates 32 in. wide riveted to their upper surfaces and forming a floor to support the concrete in the space between the girder webs. A framework of horizontal and vertical angles projects nearly 4 ft. each side of the main girders forming with them a rectangular skeleton about 11 ft. wide and 5 ft. deep which is filled with concrete except where spaces are left to clear the shafts and other mechanism.

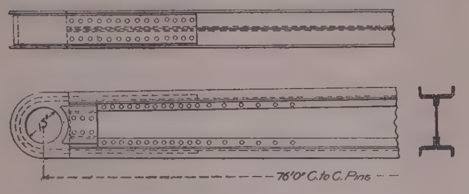
Two motors, each of them with a capacity sufficient to operate the bridge alone, are coupled to opposite ends of the 1½-in. horizontal transverse shaft, *D*, on top of the counterweight and may be used separately or together to drive it. This shaft, two reducing gears and an intermediate shaft, *C*, operate the two 4-in. driving shafts, *B*, that have at their extremities double pinions engaging the gears on the truck wheels. Two hand cranks keyed to the auxiliary shaft *E* operate reducing gears through which the driving shaft may be operated independently of the motors if the latter are out of commission.

The operating struts, 76 ft. long on centers, have an I-shaped cross-section made with a solid web plate and eight 6 x 3½-in. flange angles riveted together in pairs back to back to make the double Z-shape cross sections for the flanges as indicated in the cross section of the member. The web is tapered from a depth 24 in. at the center to 17 in. at the ends and the bearings are alike, each of them consisting of a steel saddle casting bored for a 13-in. pin and seated on the milled end of the strut to which it is attached by a U-shaped strap of 11 x 1½-in. cross section engaged between its flanges and those of the strut and riveted to the latter.

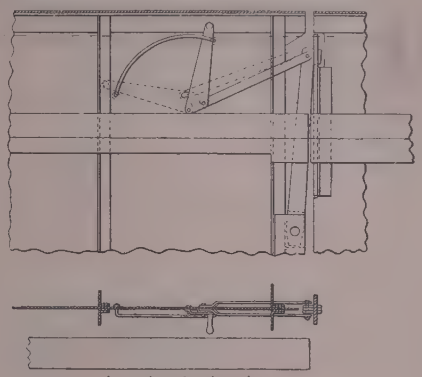
The 10-in. hinge pins for the bascule girders have a bearing 22 in. long in the girder castings and project 12½ in. beyond them at each end to engage the cast steel journal boxes bolted to the pedestals. The latter are double plate girders about 5½ ft. high and 10 ft. long over all with their upper corners notched and reinforced with flange angles to give bearing to the horizontal, vertical and inclined faces of the castings. The girder web is double and is reinforced by pairs of vertical web-stiffener angles under the casting seat and by two pairs of 5 x 5-in. bent angles which lead from the pivot at an angle of about 40 deg. with the horizontal to the intersection with the bottom flange whence they are continued to form a seat for the end vertical post of the approach spans.



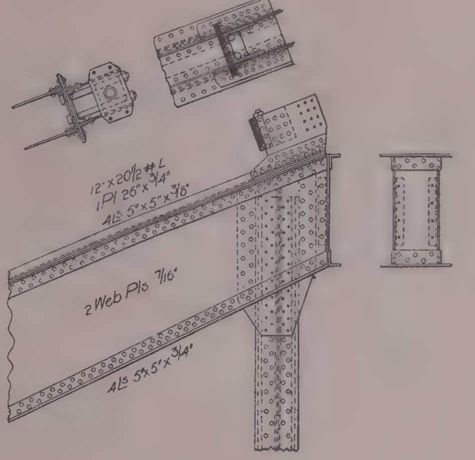
Counterweight, Mechanism and Truck.



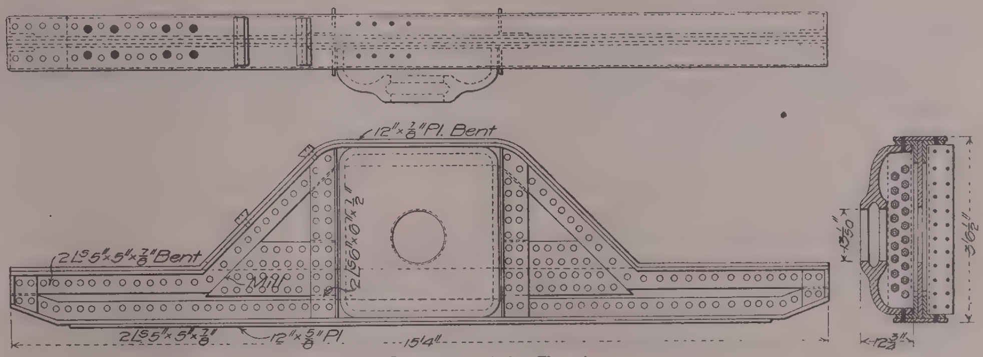
Operating Strut.



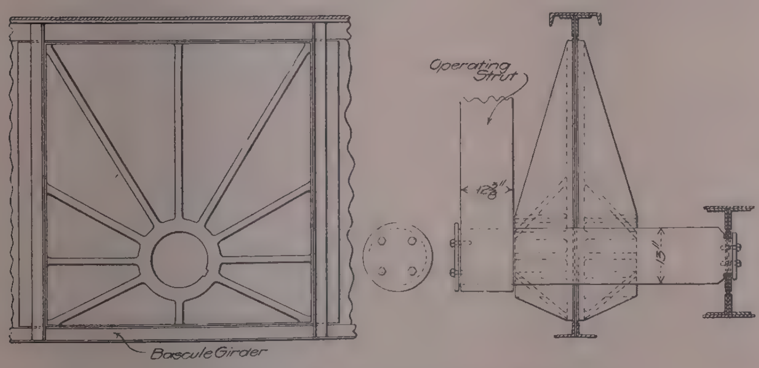
Latch Mechanism.



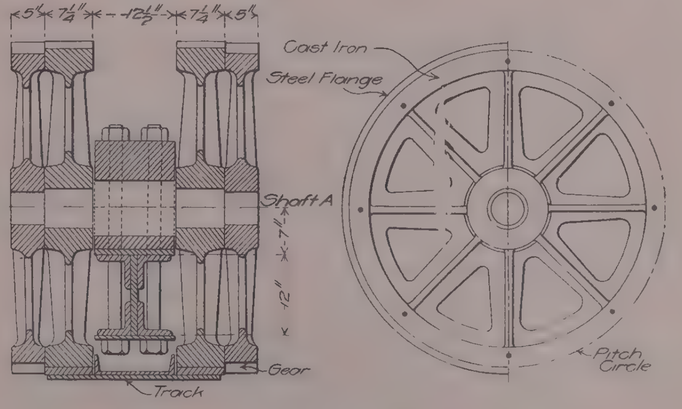
Counterweight Track and Stop.



Counterweight Truck.



Strut Pivot Bearing in Bascule Girder.



Sectional View of Truck Wheel and Gear.

Each girder has a base plate 19 in. wide with the outer edge reinforced by transverse gusset plates attached to the vertical web stiffener angles and the two girders connected by the base plate under the side span and by the pivot on a rigid pedestal bonding the bascule and side spans together and distributing the load over an extended surface of the pier masonry. The pivot is high enough and the clearance between the pair of girders is great enough to afford space for the rear end of the bascule girder to revolve inside the pedestals, clear of the masonry.

As the operating struts are connected to one side of the bascule girders only, they produce unbalanced shears and the stresses in the pivots are very large. The 13-in. pins through the outer ends of the bascule girders are about 48 in. long and have a continuous bearing 2 ft. 4¼ in. long in the girder. The operating strut is connected to the outer end close to the girder bearing and the inner end of the pin projects nearly 2 ft. beyond the girder bearing and is shouldered to a diameter of 8 in., to engage a hole bored through a web in the floor stringer. The ends of the pin are faced square and are covered by flat steel discs 1 in. thick which are secured by four 1-in. tap bolts in the end of the pin and lock it in position.

The side spans were assembled on falsework in the usual manner but the bascule spans were assembled in vertical planes supported on their hinge bearings. The erection was mainly accomplished by a floating derrick with a 70-ft. boom of 15 tons capacity. The construction of the sub-structure was considerably delayed and its cost increased by the difficulties of removing the stone embankment of the former bridge and by difficulty in securing the long piles required in some of the footings. The tidal current was also so strong that it was impossible to carry on work during a portion of the time every day and the scour was so great that it was necessary to protect the banks of the channel by 4,000 tons of rip-rap stones.

The bridge has been designed and erected under the direction of Messrs. Chas. Alexander, J. Herbert Shedd and N. B. Church, commissioners. The designs were made in accordance with the requirements and specifications of Mr. O. Perry Sarle, chief engineer, by Mr. Augustus Smith, New York, examined by Prof. A. H. Blanchard, of Brown University, Providence, and revised by Mr. J. R. Worcester, consulting engineer, Boston. The contract for the construction of the approaches was awarded to Beattie & Wilcox, of Fall River, Mass., and that for the construction and installation of the drawspan to Mr. August Smith, New York. Subsequently Mr. Smith retired and the steel superstructure was fabricated at the shops of the Boston Bridge Co.

The Great Road Improvements in Cuba.

The feature of the recent report on Cuban conditions by Governor Magoon which will most appeal to engineers is the description of the great scheme of road improvements that has been inaugurated under the provisional government. During half the year there is practically no work for about three-fourths of the men who are employed for the remaining six months on sugar plantations, and the most important economic question on the island, according to the report, is that of securing employment for these men in the periods between harvests. Another problem is the reduction of the enormous cost of transportation. When the Spanish rule ceased there were only 256 km. of highways on the island, and the agricultural products were hauled to market over trails that were barely passable during the dry season and wholly impassable during the wet season. As the principal sources of wealth in Cuba are sugar, tobacco, timber, fruits, vegetables and iron ore shipped to foreign countries, the improvement of the roads was begun at once by the government of intervention and continued by the republic, so that on Sept. 30, 1906, there were 610 km. of highways open for use.

When Governor Magoon took charge of the provisional government in October, 1906, he determined that the desirability of giving work to the unemployed sugar harvesters and the need of better transportation facilities made it desirable to increase road construction and other public works during the dead season, and orders were issued to the department of public works to prepare a general plan for a system of macadamized roads throughout the island. The torrential rains of the tropics make it unwise to construct dirt roads. The instructions to the department of public works were to plan a system of roads which should consist of a highway running east and west, approximately through the center of the island, with branch roads running north and south to at least one harbor on the north and one on the south coast of each of the six provinces into which the island is divided; the equipment of said harbors for handling cargoes easily and quickly; and the erection of lighthouses and placing of buoys along the coast where needed, thereby inducing ocean-going crafts to frequent the coast and securing the competition necessary to reduce the price of ocean transportation; at the same time the increased traffic resulting from the development of the country will give ample compensation to the railroad and steamship lines for such reduction. In attempting to execute these orders the department of public works found itself without necessary personnel and equipment, but these were supplied as soon as possible. The provisional administration desired to have everything in readiness to commence work on this large endeavor at the close of the sugar-harvesting season in May, 1907, but the work was retarded, at first by the fear that the national revenues would be diminished as a result of revolution and cyclone, and, second, by the difficulty in securing competent personnel for preparing the plans and specifications required for the execution of the work.

While the plans were being made, effort was made to locate contractors with sufficient means and machinery to do the work which would be entered upon during the present fiscal year, and it was found that there were only a few contractors so equipped and that they did not possess sufficient amount of machinery to do the desired amount of work. Thereupon the government decided to contract as much of the work as possible and to do the remainder for the current fiscal year by administration. This necessitated the purchase of a large amount of road-making machinery, such as steam rollers, steam shovels, graders, traction trains, etc. Considerable time passed before the government and the contractors could secure the necessary machinery—in fact, all that is required has not yet been delivered, but much of it has been received and other deliveries are contracted for and are being made from time to time. Bids were called for by public advertisement, but it was impossible to get the work started until late in July, and it was the latter part of August before it was fairly inaugurated.

It was impossible to completely execute the plan of public improvement above outlined within the period fixed for the continuance of the provisional administration, but the general plan is adopted and has already received unanimous approval. The detail plans, specifications, etc., will be completed, the public works department sufficiently expanded and trained personnel secured, the machinery purchased, delivered, and installed, and the work sufficiently advanced to make it fairly certain that the plan will be carried out within a reasonable period. Induced by the adoption of the general plan and the call for bids, a number of private concerns have invested large sums of money in purchasing outfits for executing contracts on this work and will materially aid in inducing the continuance of the work.

Attempt was made to ratably distribute this work in all the provinces and to begin work in each at about the same time. The obstacles to overcome were so numerous that it became necessary to concentrate effort on one province at a time. Pinar del Rio was selected as the first, largely because it was feared at that time that the tobacco crop of that province for the year 1906 would be nearly if not a total failure; timely rains, however, made the crop satisfactory in quantity and quality. As soon as the preliminary work in Pinar del Rio Province was completed, Habana Province was taken up, and shortly thereafter Matanzas Province. The work is not yet fully started in Santa Clara, Camaguey and Oriente provinces, although work on some of the roads commenced late in the season and other roads are being projected.

On September 30, 1907, the mileage of highways had been increased to 786 km. and 697 km. were under construction, the greater part of which will be completed by the end of the current fiscal year, making a grand total of 1,484 km. with all bridges and culverts that are required to protect the roads.

Important highways are given a crowned metaled width of 5 m., with drainage, ditches, culverts, and bridges. Telford is used where the soil is soft or drainage is poor. These are termed "macadam roads" or "highways." Less heavily traveled roads are drained, graded, crowned, and provided with culverts and bridges and are metaled only where the ground is soft. These are termed "improved roads." The figures shown in the preceding paragraph include both classes of roads. The highways cost from $6,500 to $15,000 per km., according to the difficulty of obtaining suitable road metal, and the nature of the country. Efforts are being made to reduce the cost by the introduction and extensive use of road machinery.

The Cuban congressional appropriations for road work were made in comparatively small amounts and for widely scattered localities, with the result that several years were required to complete a road between two objective points; the contracts were too small to warrant the purchase of expensive plants, and the roads when constructed did not connect into a well-considered system which could be maintained economically. In April, 1907, a definite program was adopted for the construction or improvement of 2,304 km. of roads at an estimated cost of $13,000,000, to be expended during a period of three years. In addition to this, as funds are available, the short stretches of roadway begun with congressional appropriations and not included in the general program are to be extended to their various objectives. In addition to the roads above provided for and which are those of most immediate necessity, the need for at least 3,000 km. more can now be seen. In the absence of a sufficient number of civilan experts, by authority of the commanding general of the army of Cuban pacification, 89 km. of road in Pinar del Rio are being constructed under the supervision of the officers and men of the Third Battalion of Engineers, U. S. Army, under the command of Maj. M. Patrick.

Besides the large number of bridges included in the general appropriations for roads, separate appropriations have been made since Jan. 1, 1906, for 79 bridges. Of these, 9 have been completed, 59 are under construction, and 11 are under study.

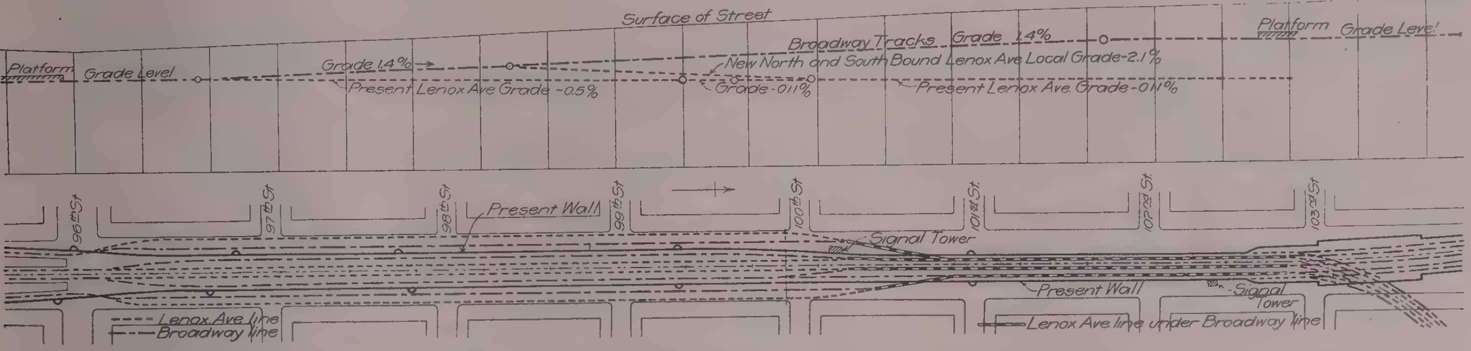
Works of improvement are in progress in the harbors of Habana, Matanzas, Cienfuegos, Santiago, and the Isle of Pines. A project for extensive betterments in the harbor front of Habana has been prepared, as well as projects for work in a number of other ports and channels. Two new dredging plants have been contracted for and will soon be ready for work. It is proposed to carry on this work as fully as funds permit.

The existing lighthouses are 34 in number. During the last year one new lighthouse has been built, 13 repaired, buoys and beacons repaired and re-established, the installation of the improved lighting system continued, and the construction of six new lighthouses has been authorized. Work on two of these lighthouses will be begun during this fiscal year.

The Production of Common Brick has reached such large proportions in this country that in 1906, according to the United States Geological Survey, only pig iron, copper and bituminous coal exceeded the clay products in value and of the latter products the product of greatest value was, as heretofore, common brick, of which more than ten billion were marketed during the year. Their value amounted to $61,300,696, an increase of $93,687 over the value for 1905, and constituted 47.3 per cent. of the value of the brick and tile products, and 38.07 per cent. of the value of the entire product of the clay industries. The largest production of common brick in 1906 by any one State was reported by New York, whose output amounted to 1,535,579,000 brick, valued at $9,205,981, or about $6 per thousand. This quantity represents 15.31 per cent. of the entire output of the country, and the value is 15.02 per cent. of the total. Next to New York, the largest producer of common brick was Illinois, which reported an output of 1,195,210,000 brick, valued at $5,719,906, or $4.79 per thousand. The only other State reporting more than a billion common brick was Pennsylvania, whose marketed output amounted to 1,027,541,000 brick, valued at $6,586,374, or $6.41 per thousand. The average price per thousand for common brick in 1906 ranged from $9.69 in Wyoming to $4.38 in Kansas, the average price for the whole country being $6.11.

Proposed Track Changes at 96th Street, New York Rapid Transit Subway.

In order to relieve the congestion of traffic which occurs in the New York Rapid Transit Subway at the 96th Street station, extensive track changes have been proposed which will eliminate track crossings at the same grade and change the point of separation of the express and local traffic on both the Lenox Avenue and Broadway divisions. South of 96th Street, the trains of both divisions run over the same tracks, of which there are four in all, two for express and two for local service. At 96th Street, the traffic of the two divisions is separated, the Broadway trains continuing on a grade about parallel to that of the street above, and the Lenox Avenue trains dropping down a 0.5 per cent. grade into a sub-subway which diverges from Broadway at 103d Street and continues on under Central Park to Lenox Avenue. At the present time the cross-overs by which the separation of the traffic both north and south bound is effected are placed at the north end of the platform of the 96th Street station and to the interference of trains on these cross-overs is due the congestion which the proposed changes are intended to relieve. In order to get from their respective division to the common running tracks south of 96th Street, it is necessary for the Lenox Avenue local tracks and the Broadway express tracks to cross each other at the same grade. The resulting interference stalls local and express trains of both divisions, causing considerable delay and cutting down materially the efficiency of operation. Another aggravating condition in the southbound traffic is the operation, during the rush hours of the morning, of an extra through express track on the Broadway line, so that there are three tracks carrying traffic north of 96th Street which must be handled on two tracks south of that point.



Proposed Track Changes Between 96th and 103d Streets, New York Rapid Transit Subway.

The proposed change will do away with all crossings at the same grade and transfer the switches for the separation of the local and express traffic of each division to a point near 101st Street. This will be accomplished by the construction of four new trracks, two on each side of the present subway and extending from 96th to 101st Streets.

The proposition presents many interesting and difficult problems. The elimination of grade crossings is the primary object to be attained, but questions of efficient operation of the reconstructed lines, the small limits with which both grade and alignment changes must be confined, the necessity of maintaining a very heavy traffic, with trains at frequent intervals, during construction, and the high cost of making the changes, due to local conditions, have all influenced the design finally adopted.

The proposed changes are shown in the accompanying diagram, and, as will be noted, do away with any interference between express and local trains immediately north of 96th Street. Going north a break for a single track is made in the present wall of the subway at 96th Street for the local trains. Immediately outside the present wall the track divides into two separate tracks, one for the Lenox Avenue, and one for the Broadway trains. These continue side by side at the same grade, which is that of the present Broadway line, until near 98th Street, where the Lenox Avenue trains drop down on a 2.1 per cent. grade, which continues until the difference in elevation is sufficient to allow the Lenox track to pass beneath that of the Broadway line. In this position, one vertically above the other, they connect with their respective tracks.

It will be noticed that there is absolutely no change in the present trackage for handling the express trains under the new arrangement, those of the two divisions being separated by a switch at 96th Street and following the same tracks at the same grades as now in use. Between 101st and 103d Streets the Lenox Avenue local will make use of a third track in the sub-subway, which is now dead-ended and used as a storage track. This will keep the northbound Lenox Avenue express and local trains separated until the point of diversion at 103d Street is reached.

The separation of the express and local traffic southbound is effected at 101st Street where turnouts are placed to take off the local trains in the upper level and in the sub-subway. The local tracks continue one above the other for only a short distance, the Lenox Avenue line swinging outward and starting up on a 2.1 per cent. grade to reach the level of the Broadway tracks. This is accomplished near 98th Street, opposite the point where the grade separation for the northbound trains starts. The two local tracks, now at the same level, continue parallel to 96th Street, where they merge into one and pass through the wall of the present subway.

In a scheme involving the expenditure of $850,000, the estimated cost of the changes herein described, there were naturally a great many alternative plans, and discussions and studies of these resulted in bringing out clearly the advantages that could be obtained, and also the relative value of these various advantages in order to determine which of them were to be sacrificed on account of the high costs. Some of these points are of particular interest in connection with the plans adopted and above described.

A considerable saving in cost is effected by carrying the local trains of the two divisions through the present subway walls at the same point, instead of starting to effect their separations and connections within the limits of the present subway.

Among the alternative plans was one that provided for a single northbound local track to a point about midway between 96th and 101st Streets, and the placing of a switch at that point for the separation of the trains of the two divisions. Though it possessed the good points of lessening construction cost, it would have introduced an extra slow point, and lengthened the running time. There is necessarily a slow point at 96th Street due to the stop at the station, so that by placing the switch at this point, advantage is taken of this factor. For this same operating reason it would have been advisable for the northbound Broadway locals to pass through on a separate track to 103d Street, before entering on the local express tracks, since a stop must be made at the station. It was considered, however, that this operating advantage did not sufficiently offset the increased construction cost. Similar reasoning would prompt the lengthening of the southbound Broadway local track, also, northward to 103d Street.

The introduction of two local tracks from 101st to 96th Streets, southbound, was made to allow for storage of trains waiting for signals to proceed on the common tracks south of 96th Street. These tracks will each hold two 500-ft. trains.

The plans provide for keeping the present grades of the tracks now in place undisturbed. The new Broadway local track will continue at the same elevations and grades as the present Broadway tracks, while the new Lenox tracks will run at the Broadway grades and elevations until just north of 98th Street, where a new gradient is introduced for overcoming the difference in the track levels of the two divisions. The continuation of this new grade backward towards 96th Street, in order to get smaller gradients, was proposed, but again the high cost made it advisable to adopt the steeper grade and save in excavation and retaining walls. The placing of the new Broadway local tracks immediately alongside of the present subway wall and at the same grade as the Broadway express track on the other side of the wall will enable the latter to stand undisturbed, which would not have been the case had the new Lenox Avenue local track been placed next to the wall.

Alternate methods of carrying on the new construction without disturbing the present traffic have received considerable attention and are now being worked out in detail. The roof of the subway is very close to the street level at this point and consequently all of the reconstruction work will have to be carried on by the cut and cover method. This will introduce a difficulty, in providing the maintenance of the street traffic. Further difficulties will be experienced because of the changes which will have to be made in sewers, water and gas pipes and electric conduits which were disturbed in the construction of the original subway. Special fittings and changes then made in them will make their handling at the present time even more difficult than were the original changes.

The proposed plan has been worked out under the direction of Mr. Henry B. Seaman, chief engineer of the Public Service Commission, and has been accepted by the Interborough Rapid Transit Co., Mr. Geo. H. Pegram, chief engineer.

HEATING BY WASTE HEAT from enameling furnaces is practiced at the plant of the Carnahan Stamping & Enameling Co., Canton, Ohio. The warm air from the furnaces is distributed by a fan blast.

Investigation of Collapse of Filter Roof During Construction at Lawrence, Mass.

A paper (somewhat condensed) read before the New England Water Works Association by Sanford E. Thompson, M. Am. Soc. C. E., Consulting Engineer, Newton Highlands, Mass.

My acquaintance with the Lawrence filters began toward the latter part of May, 1907, when, at the request of Mr. Morris Knowles, I made an examination and report upon the failure of the roof. The investigation involved an examination of the concrete and the materials composing it, besides a general inspection of the condition of the filter after the collapse. [An illustrated description of this accident was printed in The Engineering Record of April 27, 1907.]

The concrete was laid in three divisions: first, the floor with its inverted groined arches; next, the columns, which were dowelled to the floor by two pieces of 1-in. iron pipe projecting about 8 in. up into the column; and finally the roof of groined arches resting upon the columns and supported temporarily upon centering constructed in the usual manner for this type of work.

Various causes delayed the construction, and it was not until Nov. 1, 1906, that any concrete was laid upon the roof. At this time a length of 8½ bays of floor, out of a total length for the entire reservoir of 21 bays, and 8 rows of piers had been placed. Of the roof, 7½ bays were laid before the closing down for the winter, as follows: Nov. 2, 1906, two and one-half bays laid; Nov. 9, 1906, one bay laid (from 2½ to 3½); Nov. 23, 1906, two bays laid (from 3½ to 4½); Dec. 17, 1906, two bays laid (5½ to 7½). The forms for the two last bays (5½ to 7½) were up and ready for concrete on the last day of November, but they waited until the middle of December to get a temperature as high as 28° F. in the morning, with prospect of a good day.

The fall and winter of 1906-7 were unusually cold, and as this had an important bearing upon the failure, I have prepared in the accompanying curve of the temperature from Nov. 1, 1906, to June 1, 1907. The temperature dropped below freezing the last of November, and there was scarcely any real thawing weather until well into March. At the time the last two bays of concrete were laid, Dec. 17, the average temperature was just above freezing, but that night it dropped below freezing and the next day but one reached 6° above zero.

As soon as the concrete was laid in the arches, they were covered with straw to a depth of 6 in. and later about 2½ ft. of sand and gravel were placed on top of the straw, the two last arches being filled upon about two or three weeks after they were laid.

The contract required, with reference to work in cold weather: "In case any unforeseen contingencies arise which will prevent the work being completed by Nov. 15, 1906, and it becomes necessary to do work in the winter weather, no embankment shall be made and no concrete shall be mixed, nor placed, nor masonry laid, nor any other operation performed, likely to be interfered with by cold during any of the months of December, January and March and thereafter until the frost is out of the ground, unless permission be obtained from the Engineer. If, however, the Engineer is of the opinion that any operation can be satisfactorily performed during these months, he may give the Contractor a special written permit, which permit shall define the work and the conditions under which such work may be done and such conditions shall be faithfully followed.

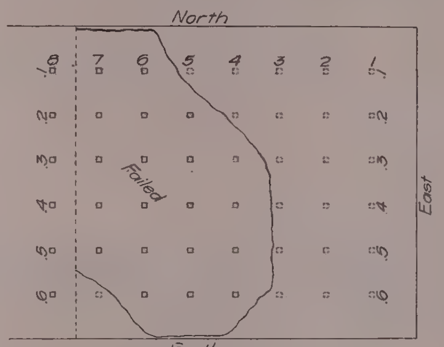
"The Contractor shall be responsible for all defects in the work done during these months which may arise from the action of the elements, notwithstanding such permit and additional precautions taken. He shall make good such work, and shall make good any work destroyed or damaged by the frost, even though built at any other season of the year."

No permit was given to the contractor to continue work in December.

In the diagram of the easterly end of the filter where the collapse occurred, the distance between the east end and the dotted line represents a length of about 110 ft. out of a total length of reservoir of 313 ft.

During the winter, centering had been removed from the first three bays of the roof, leaving a length of 4½ bays with the centering in place.

On the day previous to the fall, the carpenters began to remove the centers from these last bays, so that at night all of the centering was down except the half centers between the seventh and eighth rows of columns, the full centers in the next bay, and the four north arches between the fifth and sixth rows. The foreman carpenter told me that when he came on the next morning, April 3, he noted that a 4 x 8-in. horizontal piece in one of the half centers was twisted, but he did not attach any importance to it. The men began to work on the north arches of bay 5-6 when a cracking was heard, and they all got out from under. The break appeared to start about the center of the reservoir, that is, about half way between the two sides, and the whole roof seemed to go down at once. Fortunately, the men were warned in time and no one was injured.



Column Arrangement.

The centers were supported by vertical posts, and while at one of the columns two braces ran from the arch, in general, I was told, only one brace was used, and this was fastened to the column at the height of the second clamp from the top. This brace, it must be noted, came against the upper part of a column which had simply its own weight and the adhesion of two short lengths of round rod to prevent its overturning. All of the columns in row 8 remained standing, but one at about the center of the reservoir, where the break was said to start, was slightly canted. In the next row four piers were standing, but all of them tipped, including the pier in the row under the southwest arch. The columns in the other rows were nearly all broken. Pier 8.3, which was slightly canted at the time of the fall, was afterward pried over, and the cleavage of the base from the floor was smooth, as one would expect of a joint between concrete laid on two different days. The two steel dowels which projected into the pier had pulled out, leaving clean surfaces.

Several of the columns in row 3 were tipped toward the west, and a crack had opened at the top, at the spring line of the arch, about ½ in. wide. Three columns were out of plumb from 1 to 2½ in., and these were also cracked at the base as well as the top. In the portion of the roof remaining I noticed cracks, mostly along the center line of the arch.

The concrete at the time of the fall was so soft and crumbly that it could be readily pulled to pieces. At the time of my visit it was fairly hard, evidently having hardened very much since the failure. The stones, however, pulled from the concrete more easily than they should have done in first-class concrete, indicating that even at this time the concrete was not very strong. Concrete from the surface of the roof was noticeably weaker, even at date of my visit, than the concrete next to the centers.

In certain places pieces from the top surface of the roof were much discolored. Examination showed that the concrete had been in contact with manure contained in the straw, while other neighboring portions of the roof surface, which were covered with clean straw, were of normal color. The discolored portions, the color extending to a depth of about 1 in., were softer than the rest of the concrete and readily flaked when rubbed between the fingers. Although this did not extend deep enough to be in itself responsible for the failure of the roof, the condition was such as to show very conclusively that manure is a bad thing to place in contact with green concrete, and that when straw covering is employed, it should be free from manure.

In this connection I may say that I recently had occasion to examine a barn floor of concrete, and also several concrete drains in this floor, which had been in use for a number of years in continual contact with manure, and found the surface absolutely hard and perfect. A tank containing manure was also in similarly good condition. The conclusion, therefore, may be drawn that manure is likely to injure green concrete while not affecting well-made concrete after it has set and hardened.

The sand and gravel used for the concrete were from a pile which had been excavated from the site of the filter. This material was screened into gravel for the coarse aggregate or ballast, and sand. Four samples of the sand were taken, and two samples of the screened gravel. Examination of the sand and of its analyses shows that it is all of medium quality, containing a somewhat excessive percentage of dirt for maximum strength, but none too much for water-tightness. Examination of the analyses of the gravel shows a large percentage of material under ¼ in., the sample with the least fine material screening 20 per cent. below ¼ in., although the contract specifies that "all particles smaller than ¼-in. shall be screened out." The specifications required proportions of 1:3:5. If 20 per cent. of the gravel is below ¼ in., and therefore sand, the proportions are actually 1:4:4, thus giving a concrete greatly inferior in density and strength to that required by the specifications. Many of the gravel stones were covered with a coating of very fine clayey sand, which after drying in the laboratory and screening by hand for five minutes did not entirely come off. Tests by Mr. Howard A. Carson (recorded in the Seventh Annual Report of the Boston Transit Commission, 1901, p. 39) show one-third greater strength for concrete made from washed gravel than similar concrete made with gravel coated with a thin film of dirt. The excess of fine material tends to make the concrete not only weaker but slower in setting and hardening.

The contract specified that the gravel "shall be washed if necessary to render it sufficiently clean," but this was not done.

The temperature records taken at Lawrence during the winter of 1906 indicate only a very few days at which the temperature was above freezing.

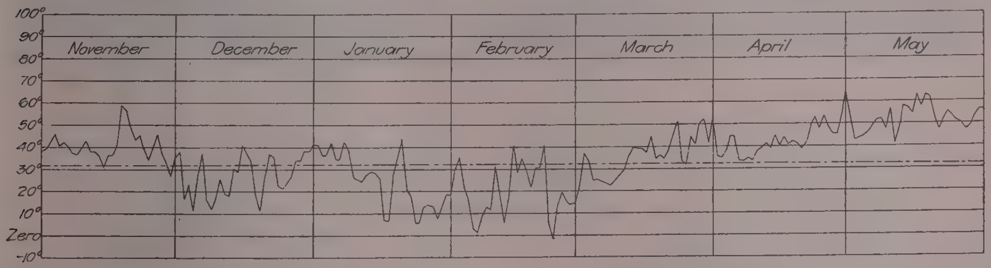
As already stated, the last arches were not laid until Dec. 17. On the following day, as shown by the curve, the temperature dropped below freezing, and there were only a few days when the temperature was above freezing before the earth covering was placed. The covering naturally tended to equalize the temperature, so that the concrete would not then have the full benefit of the occasional warmer days during the winter and early spring.

It is common knowledge that continued cold prevents concrete from reaching its normal growth in strength. Tests at the Watertown Arsenal (see Taylor and Thompson's "Concrete, Plain and Reinforced, p. 421), and elsewhere, the results of which are readily available, have brought out this point clearly, showing that if the temperature is maintained below freezing the cement has, after several months, only a fraction—on the average we may say about one-third—of the strength that it would have reached with a temperature of 70° F. Even a temperature as high as 39° F. retards the hardening so that the strength may not be more than two-thirds of what would be attained at 70° F. As soon as any of the specimens were removed from the cold and placed in a warmer temperature the hardening was accelerated, and a strength nearly normal was soon reached.

At Lawrence the effect was similar, the concrete rapidly gaining strength after exposure to the warmer atmosphere in April and May.

The contract specified: "The contractor shall notify the engineers when he proposes to strike centers, but no centers shall be struck opposite the outside walls, until the embankment has been completed to the springing line and no other centers shall be struck until at least five rows of vaulting beyond have been completed."

The five rows of centering which are required to remain in place at all times are evidently for the purpose of allowing the concrete to set and also to take up the thrust of the arches due to temperature or unequal loading. The contractor evidently assumed that the provision was only for the purpose of giving time for the concrete to set, for he was removing the forms with no diagonals left in place, except a few braces placed against a row of piers which had only their own weight to keep them in an upright position.



Average Temperatures at Lawrence in the Winter of 1906-7.

Without attempting to analyze the thrust of the arches, it is evident that if the half center at the end had been loaded with earth to the full height, it would have balanced the pressure from the next arch, so that the line of thrust from all the arches would have come directly into the piers. However, in filling a roof like this, the earth cannot be carried square to the edge, but slopes off, probably in such a case as this at a slope of 1 to 2 or 1 to 3, so that there must be a thrust from the arches beyond it if they are unsupported.

The assumption that the thrust was a factor in the fall is strengthened by the facts that, (1) one-half of the bay between column rows 3 and 4 was laid as late as Nov. 23, thus having only 12 days more to set with the temperature slightly above freezing than the outer bays, and yet this bay suffered the removal of the forms without apparent damage; (2) the bay between column rows 5 and 6, half of which was laid on the final date, Dec. 17, 1906, did not fall on the day when the forms were removed from the first portion of it, although unreinforced concrete falls quickly with but slight warning; (3) warning of failure was given by cracking of the centers and apparently commenced in about the middle of the reservoir near pier 8.3, which was tipped from the thrust of the diagonal braces against it.

The data presented enable us to reach definite conclusions in regard to the causes which contributed to the failure.

The design of the groined arch roof is one universally endorsed, being similar to that adopted with satisfaction in many other filters built from the year 1895 to the present time. It is consequently impossible to attribute the failure of the Lawrence filter roof in any way whatsoever to the design.

The causes of the failure, therefore, must lie in the construction. After removal of the forms supporting the roof, the fall appears to have been due to a combination of two causes, neither of which alone would probably have occasioned the accident: (1) The thrust of the arches; (2) the weak condition of the concrete because of, (a) low temperature which retarded the hardening, (b) improper screening of gravel, producing an excess of sand which tends to make concrete slow in hardening, (c) dirty gravel, reducing the strength of the concrete.

All of these sources were probably contributory to the fall. The subsequent hardening of the concrete indicates that no trouble could have ensued if the forms had remained for a longer time and until more arches had been placed.

Reinforced Concrete Piers for Baltimore

The new piers at Baltimore, for which bids have just been invited by the Harbor Board, are to be of reinforced concrete construction, and not of timber, as in the case of the first group built by the city after the fire of 1904. The new group, consisting of Piers 4, 5 and 6, is the second to be constructed by the city since the fire. They vary considerably in size, Pier 4 being 220 ft. wide with a maximum length of 978 ft., Pier 5 about 200 ft. wide with a maximum length of about 1245 ft., and Pier 6 from 93 to 247 ft. wide, with a maximum length of 1456 ft. They will rest on steel cylinders filled with concrete. The cylinders are 27 ft. high, 3 ft. wide, and 10 ft. long, with rounded ends. They will be spaced on 25-ft. centers around the edges of the piers. Connecting the cylinders, just above mean low water level will be a latticed girder, consisting of four angles with double lacing. The girder will be entirely incased in concrete. Back of this girder, forming a bulkhead from cylinder to cylinder, timber or reinforced concrete sheet piling will be driven vertically and fastened to the girder. Two methods of tying back the cylinders or girders have been designed. One of these alternative plans consists in driving two reinforced concrete piles between each two cylinders, about 25 ft. back under the pier, at an angle of 30 deg., sloping toward the center of the pier, and tying each pile to the lattice girder above mentioned by means of a 12-in. 40-lb. channel incased in concrete. The other plan calls for long ties extending across the width of the pier between two cylinders on opposite sides. These ties would consist of two 12-in. 40-lb. channels, likewise incased in concrete. Timber fender piles will be driven outside the concrete girder. The decks and the curb around the outside will be of reinforced concrete. The work is in charge of Mr. O. F. Lackey, harbor engineer.

Some Lessons from a Cofferdam.

A paper read before the Ohio Engineering Society, by W. H. Boughton, Morgantown, W. Va.

The cofferdam which prompted this article has been no exception to the rule that all cofferdams give more or less trouble, and this is true, in spite of the confidence displayed by the contractor who, during construction of the dam, promised to drink all the water that should leak into it after the first pumping out. This cofferdam was used for the purpose of building a bridge pier in the middle of the Monongahela River at Morgantown, W. Va. The pier extends about 50 ft. above pool level and 12 ft. below pool level. The concrete footing is 2.5 ft. thick and about 16 x 58 ft. The contractor made his dam only 22 x 64 ft. on the inside, which seemed to the engineer to be too small for the possible conditions to be met. The risk of total loss of the dam was incurred in order to effect a comparatively small saving in its cost.

One frame for guiding and holding the sheet piles rested on the bottom of the river, and another was placed at the surface. Each one consisted of an inner and an outer rectangle made of timber hewed on two sides from about 10 to 12-in. logs. The inner and outer lines were held 7 ft. apart, and at intervals of about 10 ft. poles 5 to 8 in. in diameter extended across the interior of the dam to prevent collapsing. The lower frame was loaded with rock and sunk. The timbers were spliced by being beveled, lapped and bolted by a single horizontal bolt. This allowed the frame to conform closely to the bottom of the river. The upper frame was placed in position and the two bolted together.

Sheet piles 2 x 4 in. by 10 to 12 ft. were driven inside and against the frames. The piles were driven to refusal by hand, the penetration being only 6 to 12 in. It was found impossible to drive any heavier piles at all. Wider pieces were placed over the 2 x 4's to cover open joints, but they were not driven far.

The material of the bottom was a very firm gravel containing many bowlders. Previous investigation had indicated that rock must be near the bed of the river. Work on the construction of Dam No. 10, about one-fourth mile up the river, had disclosed a rock stratum all the way across the river, but with great irregularities in elevation, and this stratum had been used as foundation for the dam. A pit dug on the east bank of the river at the bridge site showed the same stratum 4 ft. below the river surface, and at the west side it was found nearly up to the surface. As the water was 6 ft. deep at the center it was suspected that a depression existed there and rock would be struck close to the bottom. Exploration with drills seemed to give the same indication, but, as it turned out, this was due to the numerous large bowlders that were present. One bowlder afterwards uncovered in the excavation showed the mark of a churn drill on its upper surface, so it was thought that the piles had reached the rock. Had it been so the pier would have cost about $1,600 less than it did, the contract being based on unit prices.

The space between the rows of piles was filled with material taken from the hillside without special selection and consisting of clay with gravel of various sizes. Several hundred loads were hauled on an old suspension bridge above and dumped into a long chute which was shifted so as to deliver the filling directly to different parts of the dam. As excavation proceeded material from the inside was dumped on the outside of the dam up to the surface of the water.

The first lesson taught by this example is that a proper mixture of gravel and clay is better than either material singly for filling a cofferdam. But emphasis must be laid on the word "proper." The worst leak in this dam and the most costly to stop occurred at one corner where the filling material, in flying so far from the end of the chute, segregated, and the coarse material was delivered to the corner, while the fine material was dropped nearer the end of the chute. In an attempt to stop the leak at the corner additional sheeting was driven through the filling; manure was dumped outside, and a tarpaulin was laid on the bottom and covered, but all without avail. It was necessary to build another coffer across the corner inside and then to excavate the original filling enough to get in a core of better material. The leak was then reduced, but not stopped. It continued in considerable volume at each end of this patched place. This occurred on Nov. 20-23, 1907.

The next most serious leak occurred where fine material was in excess, about 20 ft. from the above corner. It broke through at 2 a.m., Jan. 1, 1908, and was not stopped that day. It was necessary to stop the pump and let the water rise.

In other places when a new leak appeared it was only necessary to churn down a steel bar and puddle the hole a little to stop the leak, but where there was clay without gravel, whenever a hole was formed, instead of caving in, the clay arched it over so that it remained a channel for water and continually enlarged. Driving down a bar or sheeting was of no avail; a hole had to be dug down to the channel in order to stop it.

Another lesson the contractor should learn from this experience is the importance of providing for the worst conditions that may be met when the conditions are not all certainly known, instead of trusting to luck to have them all prove favorable to him. Had he in this case made his coffer 10 ft. wider it would have saved him many days and nights of worry. As it was, he barely escaped a serious loss. The stratum of rock expected was not encountered at all, not even a trace of it, but 6 ft. below the bed of the river another stratum was reached that was entirely satisfactory. The space within the coffer was so narrow that to get in at the footing and leave a channel along the side to the sump, it was necessary to dig down practically vertically. This exposed the points of the sheet piles and resulted in numerous leaks. The infiltration through the gravel below the piles increased, of course, and loosened the gravel till it caved in. In places the inner sills settled a foot or more. The river rose several times and stopped work, and after each rise the dam was found to be in a weakened condition. It would surely have been destroyed had it not been for the embankment on the outside. All connected with the job agreed that it would scarcely stand another rise. On Jan. 5, 1908, a very strong leak appeared, boiling up like a spring through the backfilling that had been placed after the first courses of stone were set, and promising to become interesting. But the same day the fifth course of stone was placed, which brought the pier above the river, and the pump was removed just in time for another rise.

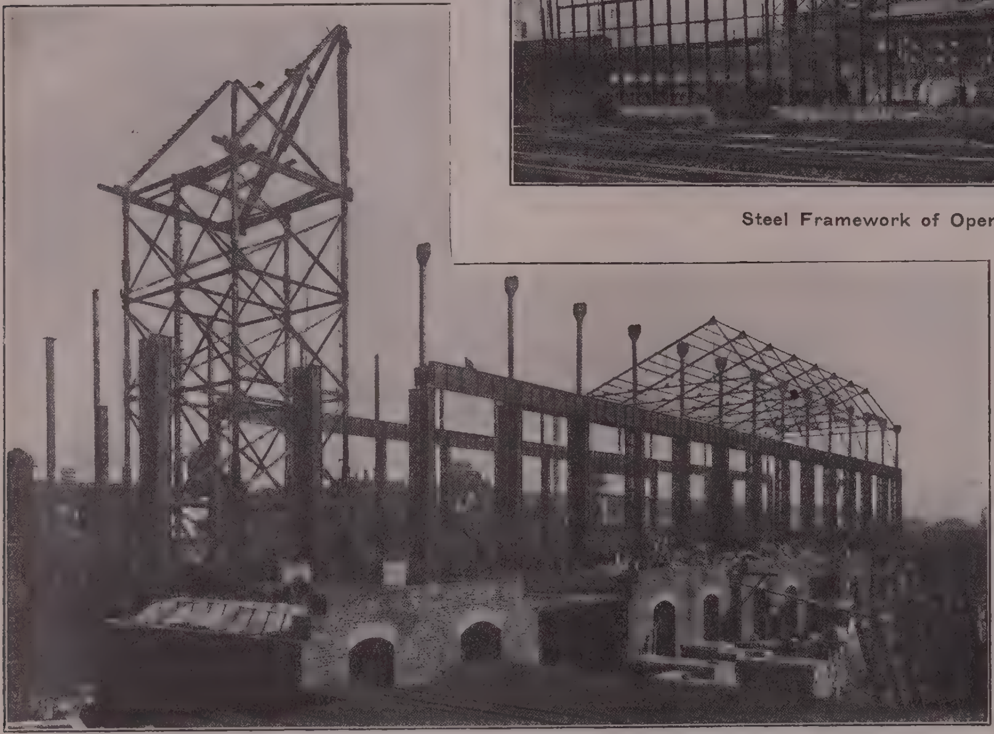
Work has since been commenced on the east shore pier. The coffer runs along the river side only and consists of simply one row of sheet piling, with a good bank of earth on the river side and a sufficient bank on the inside also. The excavation was quickly carried down to the rock stratum first mentioned and the concrete footing put in. Work was stopped Jan. 27 by high water again, but prior to that there was no trouble with water. What little water came into the hole came from the land side. At the middle pier a 6-in. centrifugal pump was kept going 24 hours a day, while at the east side a diaphragm pump operated by one man five minutes every hour kept the water out of the way.

Remarkably Heavy Floors have been designed for the new jute mill of the Columbian Rope Company, Auburn, N. Y., by the architect, Mr. Charles T. Main, of Boston. Because of the large size and weight of the machines in the second and third stories, and their vibratory effect, exceptional strength and stability were required. The columns, spaced in 10-ft. bays across the building, and on 18 to 24 ft. centers lengthwise, are of 16 x 16-in. Georgia pine. The beams running lengthwise of the mill are of the same size and material, while the flooring is of 6-in. plank, spliced and toe-nailed together, and covered with an ordinary maple top.

The New Open-Hearth Furnace Building, Pennsylvania Steel Works.

Recent extensions of the Steelton Plant of the Pennsylvania Steel Co. include the construction of five 75-ton open-hearth furnaces with an estimated capacity of 250,000 tons per year. The furnace plant, casting plant and auxiliary machinery for handling ingots, molds and materials are installed in a 172½ x 448-ft. open-hearth building adjacent to which is a 47 x 324-ft. gas producer house, both of them having steel superstructures. The framework of these buildings is both rigid and heavy, and is designed for the greatest efficiency, convenience, durability and ultimate economy. The general plan, arrangement and details are in accordance with the requirements and operation and maintenance for improved methods of steel manufacture, conform to advanced standards of structural work, and are adapted to advantageous fabrication by the standard and special plant installed in the Pennsylvania Steel Company's modern bridge shop. They are built on a large scale for important service and may be considered to exemplify high-grade up-to-date steel mill construction. The present article shows the general plan and arrangement and illustrates typical details of construction.

Steel Framework of Open-Hearth Furnace Building.


Erecting First Aisle of Open-Hearth Furnace Building.

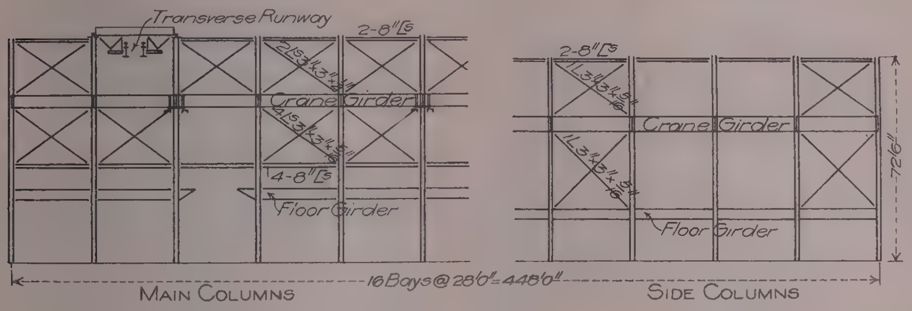
The frame work of the open-hearth building is divided into 16 longitudinal panels 28 ft. long, by 17 regular transverse bents, each of them having three roof trusses and four vertical columns, as shown in the typical cross-section diagram. The columns make four longitudinal rows which divide the building into two main aisles, 65 ft. and 72 ft. wide on centers and one 24-ft. 4-in. side aisle.

The roof over the main aisle is symmetrical about the center, and is carried by unsymmetrical triangular riveted trusses of 69-ft. 6-in. and 75-ft. 8-in. spans, each pair of which in the same bent together support a monitor truss of 37-ft. 2-in. span. The main roof has an extreme height of about 40 ft. to the peak of the monitor and its roof trusses have a clear height of 52½ ft. above the changing floor and 71 ft. above the casting floor. The side aisle roof is depressed to allow for clere-story windows below the main roof and the lower chords of the trusses have a clearance of 32 ft. above the floor.

Transverse bracing is provided by the framing in the end walls and by knee-braces in the tops of the main columns. The bents are braced longitudinally by runway girders for traveling cranes attached to each line of columns, by the main girders of the charging floor in the center and south rows of columns, by four lines of horizontal longitudinal struts connecting the columns in each row at lower chord level, by two lines of top chord struts and 34 lines of purlins in the main roof and side roof and by 12 lines of purlins in the monitor roof.

Wind stresses are distributed by continuous diagonal bracing in the horizontal panels between all bottom chords, by diagonal bracing in the planes of the top chords in end panels and in four intermediate panels of the main and side roof, diagonal bracing in the end panels of the monitor roof and by diagonal bracing in the planes of the side wall columns, in panels corresponding to those of the top chord bracing and continuing the latter system to the charging floor about 10 ft. above the ground. The outer walls are also braced additionally by horizontal steel girts to support the corrugated iron sheeting, and the center row of columns has double instead of single panels of diagonal bracing.

The columns supporting the outer ends of the roof trusses have diagonal bracing extending to the ground in the end panels and in four intermediate panels and the monitor framework has single diagonals in all vertical longitudinal panels and x-brace diagonals in the planes of the rafters in the two end panels only. The bottom chord bracing in two panels at each end of the building is sub-divided by additional diagonals at each intersection, as indicated in the diagram.

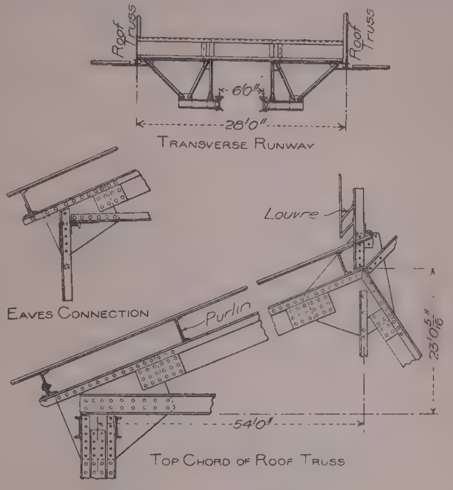


Longitudinal Bracing.

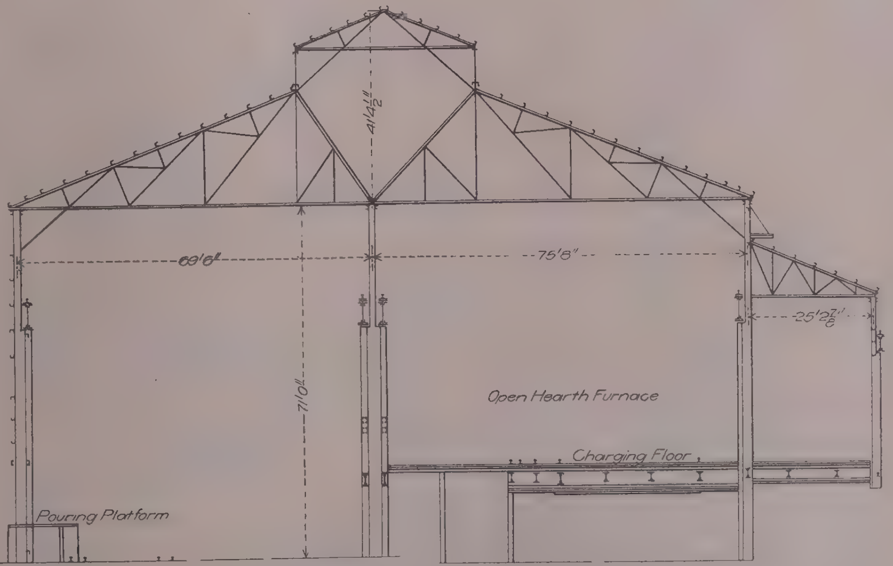
All intermediate purlins are single 10-in. 15-lb. channels, the other purlins at the intersection of the diagonals and the trusses have special cross-sections intended to provide also for the thrust received. All purlins are connected by two transverse lines of ¾-in. tierods in each panel and the diagonal bracing throughout consists of single 3 x 2½ x ¼-in. angles. The end walls of the building have intermediate vertical columns at lower chord panel points of the roof trusses, which are connected by horizontal girts from 4 to 5 ft. apart vertically and by diagonals in all panels above the level of the charging floors.

One of the main aisles is occupied by the open-hearth and melting furnaces and their appurtenances, and has a very heavy charging floor or platform about 20 ft. above the column bases which extends continuously across the side aisles. The other main aisle has an unobstructed floor space at ground level, which is used as a casting pit, provided on one side with a track platform about 9 ft. wide and 7½ ft. high. Each main aisle is commanded by two traveling cranes. Those over the casting floor having a capacity of 115 tons each, with a span of 65 ft., and those over the charging floor having a capacity of 50 tons each, with a span of 72 ft., with clearances of about 27 ft. above the charging floor and about 40 ft. above the casting floor. Two more traveling cranes of 75-ft. span and 10 tons capacity each command the adjacent stock yard and deliver directly to the charging floor, one line of its runway girders being supported by the wall columns of the side aisle.

The center columns, between the main aisles, are massive unsymmetrical members about 6 ft. wide and 71 ft. long over all, imposing a maximum load of about 1,130,000 lb. on their 40½ x 78-in. base plates. The upper part of the column, about 25½ ft. long, has a simple I-shape cross-section made with a 14 x ⅜-in. continuous web plate and two pairs of full-length 6 x 4 x ¾-in. flange angles. It is loaded only by the adjacent ends of two main roof trusses which are field-riveted through their inclined end posts and bottom chord flange angles to a large connection plate, which forms the short upper section of the column web and is shop-riveted between the column flange angles. The lower end of the web plate of this part of the column is spliced with double cover plates field-riveted to the web of the lower section of the column to which also the lower ends of the flange angles are field-riveted.



Roof Truss Details.



General Transverse Section.

The lower portion of the column has a 40½ x ⅜-in. center web, transverse to the axis of the building, which projects equally on each side of the center line on the upper part of the column. On one side it is reinforced by a single plate and several flange and connection angles forming an extension, I-shaped in cross section, with its web transverse to that of the main column and serving for the direct support of the traveling runway girder which commands the charging floor. The opposite edge of the main web is connected to one side of a closed rectangular cross section which forms a column support for the runway girders of the 115-ton crane commanding the casting floor. The lower flanges of the runway girders are seated on horizontal cap plates and their webs are field-riveted to vertical transverse diaphragms connecting them to the upper portions of the columns. The column has a base plate 1 in. thick connected to it with 6 x 6-in. horizontal angles and provided with holes for eight 2-in. anchor bolts with nuts engaging horizontal connection angles riveted to the foot of the column and reinforced by bearings on the milled upper ends of vertical stiffener angles which form pockets receiving the anchor bolts. The lower part of the column has a cross sectional area of 124 sq. in. made up with one 40½ x ⅜-in., one 24 x ⅝-in., two 24 x ½-in., and two 14 x ½-in. web plates, four 5 x 3½ x ⅝-in., four 3½ x 3½ x ½-in., two 3½ x 3½ x ⅜-in., two 5 x 3½ x ½-in., and two 6 x 4 x ½-in. flange angles. The weights of the lower and upper sections are 24,000 lb. and 2,500 lb., respectively.

The outside columns of the south main aisle carry the main and side roof trusses and runway girders for the 50-ton traveling cranes, which, together impose a maximum load of 375,000 lb., for which a total cross section of 46.5 sq. in., below the runway girder seat is provided. The lower part of the column has a 16 x 29-in. cross section made with one 16 x ⅜-in., and one 28½ x ⅜-in. web plate, one 9 x 7/16-in. reinforcement plate, three 14 x 7/16-in. flange cover plates, two 4 x 4 x ½-in., four 5 x 3½ x 7/16-in. and two 6 x 4 x 7/16-in. flange angles.

The 9-in. and 14-in. plates are provided on account of the loads transmitted from the charging floor and terminate at the connections with its girders about 20 ft. above the bases of the columns. The other materials are full-length up to the seat of the runway girders about 46½ ft. above the base except the two 6 x 4-in. outside flange angles, which are cut about 30 in. shorter and spliced at the upper ends with a single flange cover plate and the extended web to the corresponding flange angles of the upper section of the column, about 25½ ft. long, which carries the roof trusses and has a total cross sectional area of 20 sq. in. This portion of the column has an I-shape cross section made up with a 13¾ x ⅜-in. web, two 6 x 4 x 7/16-in., and two 5 x 3½ x ⅜-in. flange angles. The 5 x 3½-in. flange angles continue about 30 in. below the top of the lower section of the column and with the other flange angles and the web splice cover plates are shop-riveted to the webs of both upper and lower sections of the columns thus making a rigid splice.

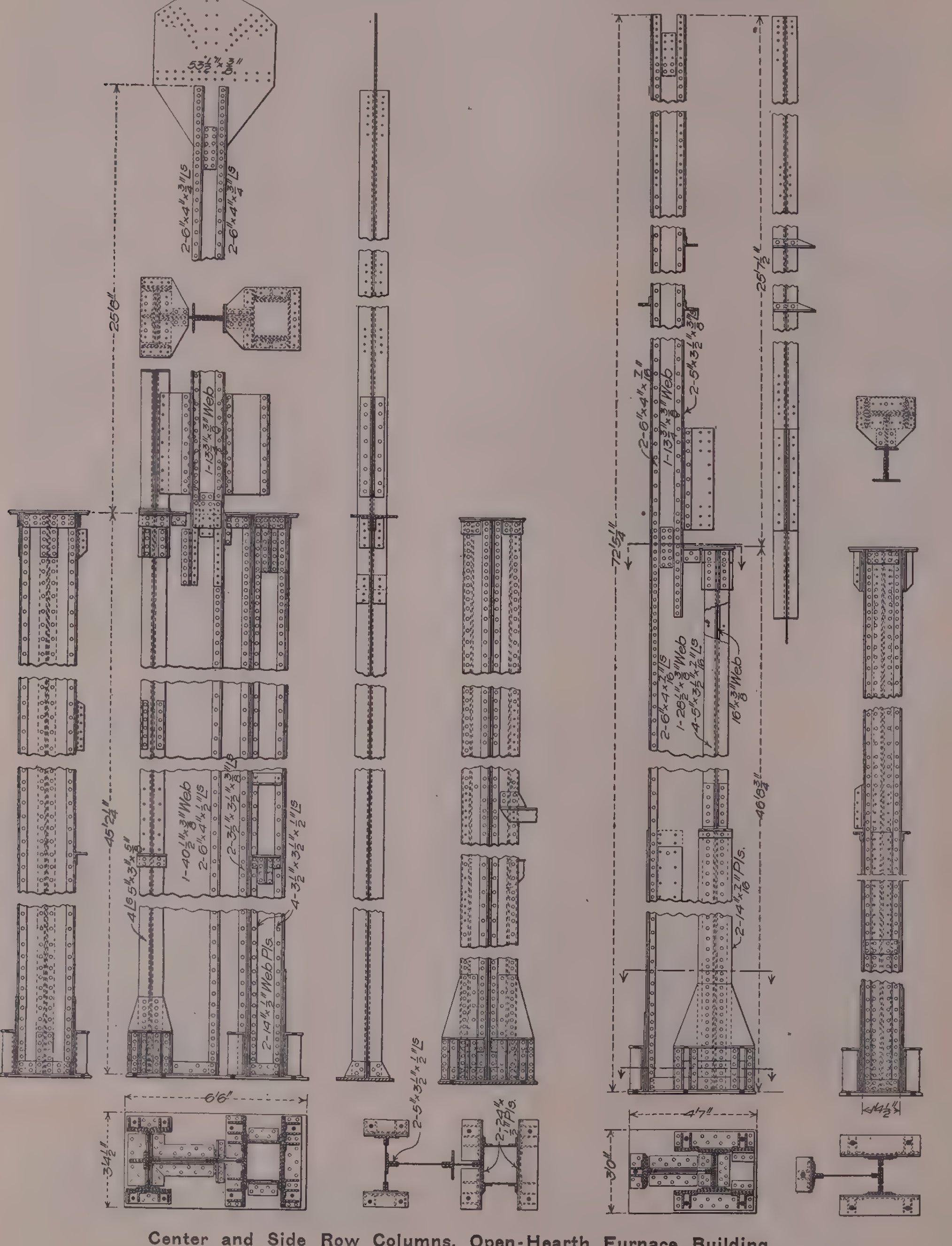
The outer row of columns in the north aisle are modifications of those in the inner row, being made with the same type of cross section reduced to correspond with the diminished load received from one runway girder instead of two. The lower portion has two distinct elements structurally forming a single section. One element has a 14 x 20-in. closed rectangular section with a cross sectional area of 46.5 sq. in. proportioned for the maximum girder crane load of 590,000 lb. This portion is made up of two 14 x ½-in. web plates, two 20 x 7/16-in. cover plates and six 3½ x 3½ x ⅜-in. flange angles, all of them terminating at the runway girder seat. The other element of this part of the column has a 26 x ⅜-in. web plate of the same length and two 6 x 4 x 7/16-in. outside flange angles cut somewhat shorter to permit the corresponding flange angles of the upper section of the column to engage the upper part of web plate and be spliced by it as previously described. The upper part of the column is similar to that in the center and south rows.

In the north, or casting pit, aisle, five bents, three panels apart, have an extra column 3½ ft. from the center of the center column which are provided for 10-ton jib cranes. Each column consists of two vertical plate girders about 18 ft. long with 24 x 7/16-in. webs 24 in. apart and 3½ x 3½ x ½-in. flanges angles latticed. The upper end of each column is secured by four vertical 1¼-in. bolts to a horizontal plate connecting it to solid-web brackets on the main column, as indicated in the detail, where the component girders of the jib crane columns are shown by dotted lines.

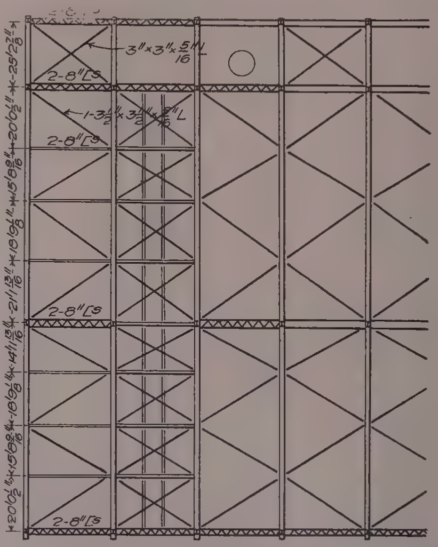
The charging floor, around the open-hearth furnaces, is proportioned for a total live load of 400 lb. per square foot, except that girders under the tracks are figured for 142-ton locomotives and those under the charging machine for 200,000 lb. on four wheels, and is an example of simple construction of extremely heavy I-beams and girders. The main transverse girders in the regular bents are web-connected to the roof columns, and in some cases have bottom flange seats on short auxiliary columns. Their dimensions vary, but those about 24 ft. long and 29 ft. apart, marked C10, 11 and 14, have a 43 x ½-in. web plate and four 6 x 6 x 9/16-in. flange angles. They are web-connected to longitudinal plate girders about 5 ft. apart, and 28 ft. long, which have 30 x ⅜-in. webs and four 6 x 4 x ½-in. flange angles. Neither transverse nor longitudinal girders have web-stiffener angles, and the top flanges of the latter are punched with sets of holes 12 in. apart for connections with 7-in. 17-lb. transverse I-beams with continuous lines of long 23½-in. flat steel plates ½ in. thick, countersunk riveted to their top flanges.

Where portions of the floor 9 ft. wide and 26 ft. long are carried between the open-hearth furnaces, the transverse and longitudinal girders are dispensed with and five regular lines of transverse I-beams, with spans of 12 and 24 ft., are supported by intermediate one-story auxiliary columns marked 91, 92, etc., with balanced cantilever extensions at the upper ends. These columns have an I-shape cross section made with four 6 x 4 x 7/16-in. full-length flange angles and a 13¾ x ⅜-in. web plate cut about 3 ft. shorter than the flange angles at the top to allow the latter to splice over a special upper section of web plates 8 ft. 9 in. wide, which, with its top flange angles, forms a girder-like support for the floor beams.

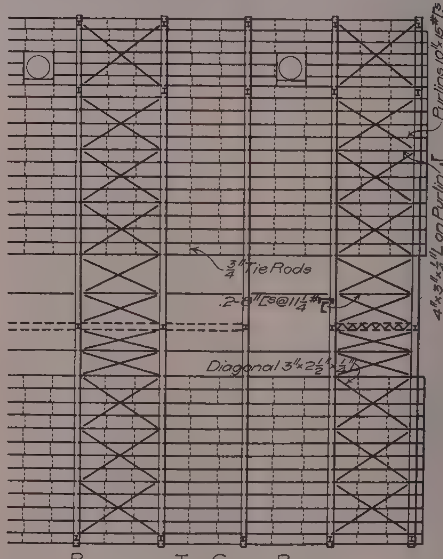
The runway girders supporting the 115-ton cranes are made with a 60 x 11/16-in. web and have a bottom flange made with two 6 x 6 x ⅝-in. angles and two part length 16 x 9/16-in. cover plates. The top flange is made with two 10 x ⅝-in. vertical side plates, two 6 x 6 x 9/16-in. flange angles and one full-length 16 x 7/16-in. cover plate. The webs are connected at both



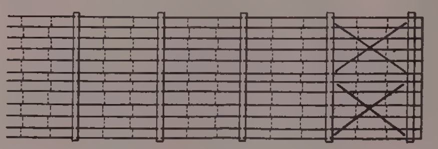
Center and Side Row Columns, Open-Hearth Furnace Building.



Bottom Chord Bracing



Purlins and Top Chord Bracing



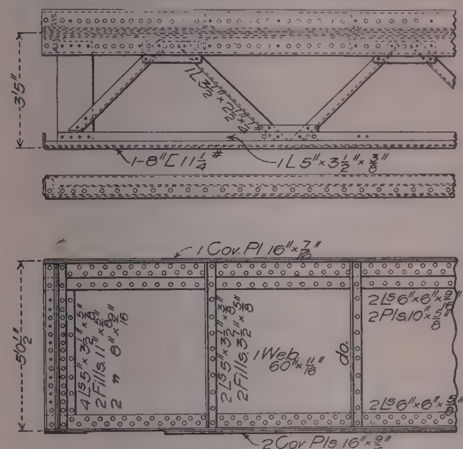
Monitor Purlins and Bracing

Transverse Roof Bracing.

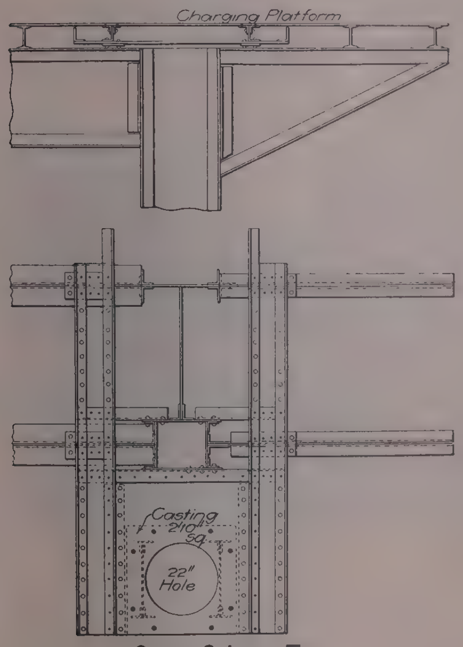
ends by full depth vertical transverse diaphragms with the upper sections of the columns.

The runway girders for the 50-ton cranes in the south aisle are of the same depth as those in the north aisle, and have 7/16-in. web plates and bottom flanges made with two 6 x 6 x 7/16-in. angles and one 14 x 7/16-in. cover plate 17 ft. 3 in. long. The top flanges are made of two 8 x 6 x ⅝-in. angles and one 14 x ⅜-in. cover plate, full length.

The two lines of crane-runway girders supported by the center row of main columns are latticed together, top and bottom, by 3½ x 3½ x ⅜-in. horizontal angles. The outside runway girders in the north aisle have their top flanges latticed to a horizontal longitudinal wall strut composed of a channel with a full length connection angle riveted to the inside of its vertical web to receive the lattice angle connection plates.



Crane Girder Bracing.



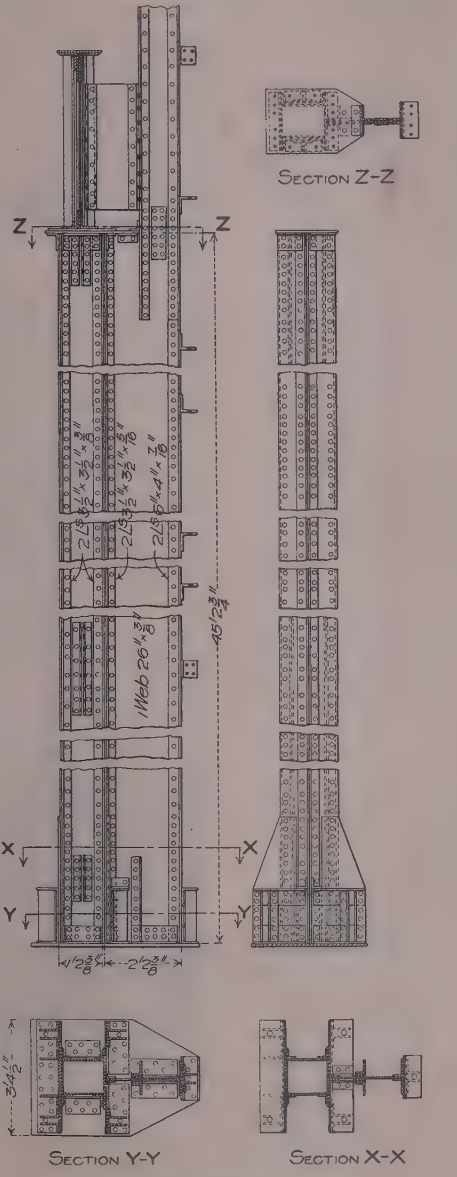
Crane Column Top.

In one panel at each end of the building, as indicated by the partial elevation diagram of the center row of columns, two lines of horizontal runway girders are supported by longitudinal beams connected to the lower chords of the main roof trusses and provide trolley tracks across the full width of the building for a special assembling car by which the girder cranes can be erected or their members removed for changes or repairs.

The roof trusses are of simple, ordinary construction, most of the members being made with pairs of angles back to back, except that in all but the monitor trusses the lower chords are made with pairs of channels and all top chords except those of the lean-to-trusses are made with a pair of angles and a vertical web plate. The inner ends of the lean-to-trusses have vertical connection angles field-riveted to the faces of the columns, and in all other cases the trusses have shop-riveted end gusset connection plates which form special top sections of the column webs and are field-riveted between the web flange angles.

The structural steel in this building has a total weight of 3,287,000 lb., exclusive of 2,322,900 lb. in the charging floor and pouring platform.

A wooden tower traveler, about as high as the top of the roof, was built for the erection of the steel framework. It had six vertical posts, connected by horizontal struts dividing it into four stories, each of which was X-braced longitudinally and transversely. The double longitudinal sills were mounted on wheels traveling on three lines of rails and carried a platform for the hoisting engine which operated two stiffleg derricks installed on top of the tower.



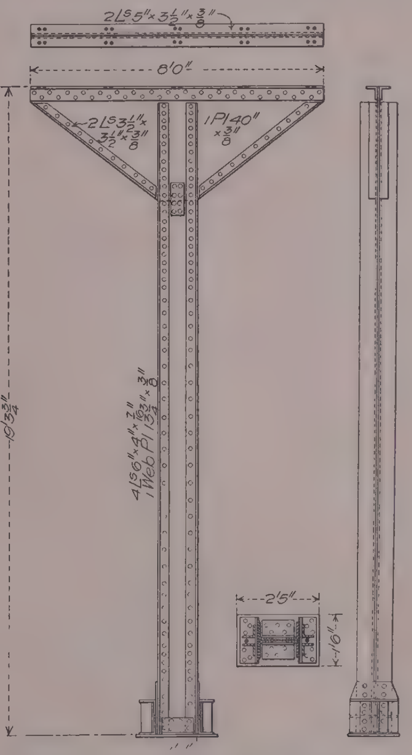
Wall Column.

The work was done under the direction of Mr. E. C. Felton, president, and Mr. J. V. W. Reynders, vice-president, and the steel superstructure was designed, manufactured and erected by the Bridge & Construction Department, Mr. Thomas Earle, superintendent, Mr. F. C. Kunz, chief engineer, and Mr. F. W. Cohen, engineer of erection.

A Ferryboat Driven by a Gas Engine has been successfully used during the past season on the Missouri River in Montana. The boat is 20 x 80 ft., with side paddle wheels driven by a 25-h.p. gasoline engine.

Small Piles for Underpinning Buildings.

Underpinning piles have recently been driven by a new method in New York. Many exterior walls five stories or more in height have footings on sand near the surface and require underpinning to protect them from settlement or undermining when excavations are carried to a great depth alongside. Instead of needling, trenching and carrying down new footings to a considerable depth, the weight of the wall can be carried directly through wet sand to deep-lying rock by vertical columns placed under the wall in its plane, with very little obstruction on the face of the wall and none on the inside of the building. Narrow vertical recesses are cut partly through the foot of the wall and in them short sections of vertical steel pipes are seated on the ground and driven down by an air hammer and an inside hydraulic jet. As fast as the successive sections are driven, new ones are added on top of them and they are spliced together by inside sleeves. When the pipe reaches the rock, the sand and earth are pumped out and the pile is filled with concrete in which vertical steel reinforcement rods are embedded, bearing at their upper ends on the cast iron caps with which the pipes are covered, which are wedged up against the masonry or against reaction beams placed in it. The piles are calculated to work under large unit stresses for the full cross-section of both steel and concrete, and great strength is claimed for piles of small diameter. The hammer is specially designed for this service and can be operated either by air or steam at a moderate pressure. Its piston is hollow, allowing the water pressure pipe to pass through it and into the pile, while it is in operation, and the water jet is delivered through a chisel-shaped nozzle which is efficient in cutting through hard pan. Both piles and hammer have been designed and used by Clark & Co., New York.



Column for Charging Floor, Open-Hearth Furnace Building.

A Power Transmission Line 120 miles long has been constructed by the Guanajuato Power & Electric Co. to transmit energy from a hydroelectric plant to the Guanajuato Mining District in Mexico. At the power plant there is a 5,000-h.-p. single horizontal unit of the Allis-Chalmers scroll-case type.

California Stove-Pipe Wells on Long Island.

For some time past the Board of Water Supply of New York City has been conducting an investigation in Suffolk County, N. Y., on Long Island, to determine whether the ground water supply there available is of sufficient quantity and of proper quality to warrant its development as a source of additional water supply for New York City, and to determine if this supply can be appropriated without injury to Suffolk County interests. In connection with these investigations a number of wells 12 and 14 in. in diameter and of various depths up to a maximum of 812 ft., have been sunk.

These wells are of what is known as the California stove-pipe variety, the name being taken from a type of well which was developed, and has been used almost exclusively up to the present time, in California and one or two other Western States. When the Board of Water Supply determined to sink a number of deep wells on Long Island, a detailed personal investigation of the California process was made by Mr. Walter E. Spear, assistant engineer, to see if the methods there in use would be applicable to the somewhat similar geological conditions on Long Island. As a result of these investigations, a California stove-pipe well rig, very much like those in use near Los Angeles, where this method of well driving has had its greatest development, has been used by the Board of Water Supply on Long Island.

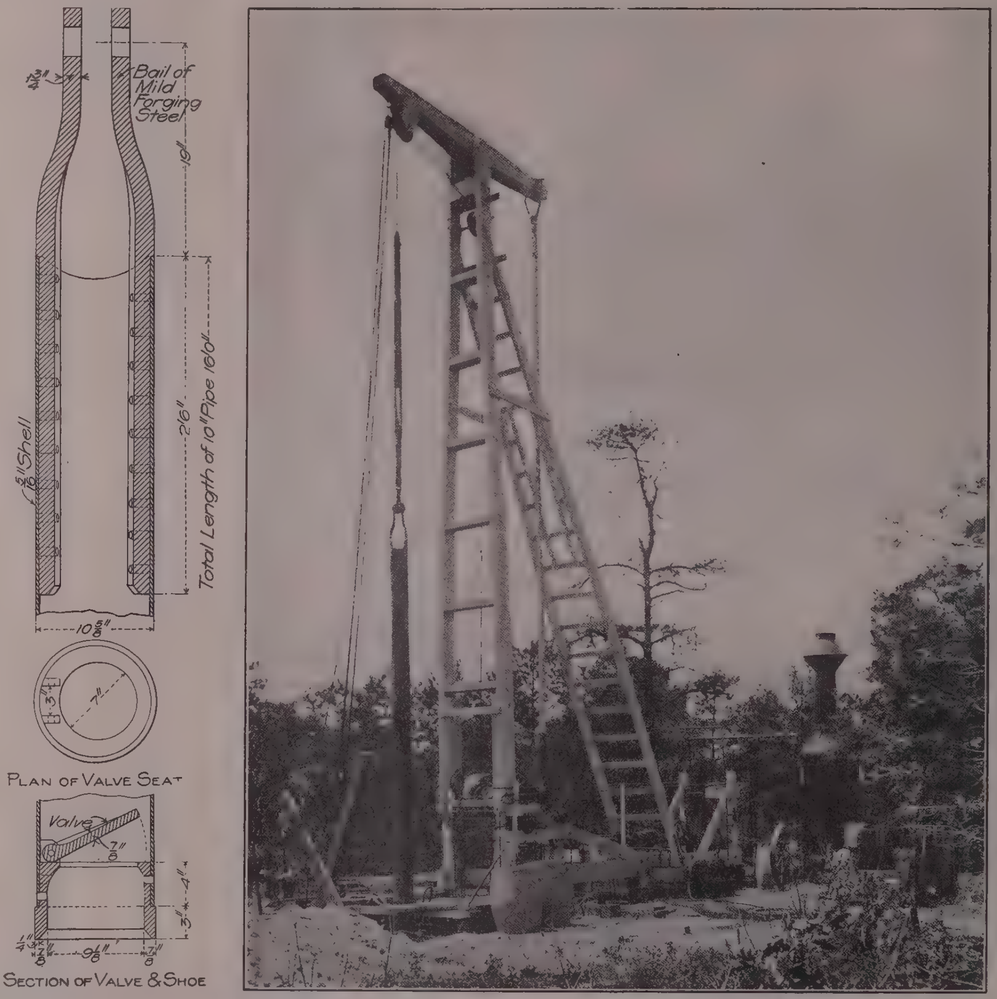
The California stove-pipe well is adapted for use where water exists in unconsolidated formations. These wells commonly vary from 10 to 18 in. in diameter, but on account of the type of tools used in driving them the larger diameters are favored. Experienced California well drivers state that a diameter of 12 in. is probably best when a well is to be driven a great depth. Wells 1,200 ft. deep have been driven by this method.

The well casing is a double-thickness, flush-jointed tube made up of thin sheet-steel cylinders 24 in. long with single-riveted longitudinal seams, whence the name "stove-pipe." The units of the inside tube are uniform in diameter and fit tightly inside the units of the outside tube, which are also uniform in diameter. The units of each tube butt together without riveting, the transverse joints of the inside tube coming about half-way between the transverse joints of the outside tube.

The well-driving outfit in use on Long Island consists of a portable walking beam derrick, of the form shown in accompanying illustration, 37 ft. high with a 12-ft. walking beam, fully equipped with suitable tools, such as sand buckets, link jars and the like, to which reference will be made later, and a set of hydraulic jacks with a pump for forcing down the casing. The derrick is equipped with a 7 x 7-in. vertical engine, which is supplied with steam by an 18-h.p. vertical boiler, mounted separately on a special four-wheel truck so as to be readily portable. This engine is rated at about 12 h.p., and is large enough for the work, but not so strong as to strip the gears or break the cable, which may very easily happen if gravel or other hard material gets between the sand bucket and the inside of the wall casing in sufficient quantity to hold the former fast. The belt drive between the engine and the operating gears is another safeguard against such accidents. An 18 to 22-in. pulley on the engine and a 54 to 60-in. pulley on the main operating gear is considered good practice among the California well drivers. The operating gear should be cut rather than cast.

The crank stroke is adjustable to three lengths for different materials. The crank is sometimes driven through a friction clutch instead of the usual positive clutch, as this permits controlling the speed of the blows of the bucket independently of the speed of the engine and, moreover, the bucket can be raised without stopping the engine to pull out the clutch. The operation of the engine is controlled by the valves and levers at the head of the derrick, as shown in the accompanying illustration.

The units of the casing are forced into place one upon the other and the whole casing is pulled down as the excavation proceeds by two or four hydraulic jacks, anchored to a plank and timber platform buried in the ground about 10 ft. Two pair of jacks are usually provided—one pair of 6-in. jacks that will exert a force of 50 tons when the pump pressure is 2,000 lb. per square inch, and a second pair of 8-in. jacks that will give 100 tons with the same unit pressure. The smaller pair are used for the first 200 or 300 ft.; better speed can be made with them than would be possible with larger ones. Later, the larger ones, or possibly all four, may be necessary. The stroke of these jacks is about 4 ft. 8 in., or a little more than enough to set a pair of tubes—one outer and one inner—and shove the casing 2 ft. without using hooks or backing up the jacks. A special driving cap is used with the jacks; it is provided with four radial lugs or ears and each piston rod has an eye with a heavy 4 x 8-in. shackle to fit over one of the ears of the driving cap. A Marsh high-pressure pump with an 8 x 12-in. steam end and two 1⅝-in. water ends is used to operate the jacks. This pump delivers a pressure of about 2,000 lb. per square inch working under 100 lb. steam pressure.



Sections of Sand Bucket and View of Derrick for Driving Stove-Pipe Wells.

The sand bucket, with which the excavation inside the casing is made, is like other well drilling buckets used for similar purposes, but is much heavier and stronger than the buckets commonly used. It is a combined drilling tool and sand pump and is designed to break up and remove or push aside large boulders, thus obviating the necessity of introducing other drilling tools, and also to handle fine sand or tough clay. These varied purposes it accomplishes admirably. The outside diameter of the bucket is made as large as possible to prevent the entrance of pebbles, but it must not be so large as to prevent good circulation between the pipe and the bucket, as this is essential. For a 12-in. well a 10-in. bucket is commonly used. The barrel of the bucket shown in an accompanying illustration is 16 ft. long and the length of the bucket over all is about 18 ft. The cutting edge is a heavy forged steel ring hot-shrunk and tap-riveted in place. The bail forgings are attached in the same manner. An extra bucket of each size is provided for use when clay is encountered; this has its shoe fitted with a vertical diametrical steel cutting edge, but in all other respects it is like the bucket used in sand.

The bail of the sand bucket is attached to a pair of 5¼-in. link jars with a 20 to 30-in. stroke, or a little more than the stroke of the bucket. These provide for a jerk or blow to the bucket when it is stuck, and are also an additional safeguard against breaking the cable. The latter is generally ¾ or ⅝ in. in diameter for a depth up to 1,000 ft. The motion of the walking beam gives the bucket a churning motion that is essential for its successful use. The length and rate of speed of the bucket stroke is varied according to the character of the material to be penetrated, but averages between 14 and 24 in., and 20 to 50 per minute, respectively. In clayey material the stroke is shortened and speeded up to 60 per minute. In soft material the bucket can be filled each time it is lowered, but in hard material only a few feet can be brought out at one time. In emptying the bucket it is lifted clear of the casing and the bottom is pulled over to one side, the bucket being lowered at the same time over the fork of two sticks, the height of which is adjusted so that the bucket falls over and empties as the cable is slacked off. It is cleaned thoroughly before being reintroduced into the well, being flushed out with water if necessary. The bucket weighs with its connections 1,000 to 1,200 lb. The arrangement of the derrick gears is such that this weight falls almost freely. Boulders of considerable size are frequently broken up with the bucket and fragments just small enough to pass the valve opening at the bottom are sometimes brought to the surface.

At the same time that the bucket is being churned up and down, the casing is advanced with the hydraulic jacks. The bucket leads the casing from a few inches to several feet, depending on the material to be penetrated; in sandy material, when the lead is about 6 in., 25 to 200 per cent. in excess of the volume of the well is taken out. Water is necessary for the successful operation of the bucket and when the level of saturation is some distance below the surface the casing must be kept filled with water until the ground water surface is reached.

Considerable experience and skill is necessary if difficulty is to be avoided in using a bucket of this kind. The operator, who holds the running cable in his hand, can tell by the click of the valve whether the bucket is digging or not; when it stops digging it is raised at once whether it is full or not. It is never allowed to remain on the bottom any length of time and never is filled to overflowing as it might bury itself or be wedged fast by gravel lodging between it and the casing. In good material a progress of 40 ft. per 8-hr. day is not unusual; the average progress on the Long Island work has been 25 to 30 ft. per 8 hr. To avoid costly experiments with untrained operators the Board of Water Supply secured the services of an experienced California well man, Mr. George W. Catey, who is in charge of the Long Island drilling rig.

When the casing has penetrated the water-bearing stratum which it is desired to tap, the casing is perforated at the proper level and the water is pumped out thoroughly to clear away fine materials from around the perforated part of the casing and collect there a natural filter of clean sand and coarser material. A so-called knife perforator is commonly used. This is operated by a line of extra heavy 3-in. pipe and makes a cut ¼ to ¾ in. wide by 10 to 12 in. long. When the tool is in place the cutting knife is dropped into position by a trip line of ¾-in. pipe with a set of small link jars at the top. The 3-in. pipe is then raised by jacks and this forces the knife through the casing and draws it upward making the perforation. The knife is then thrown back with the trip line and tool is put in position for another cut. About 4 cuts in a single circumference is considered the maximum safe number. They are made alternately in diametrical planes at right angles to each other to avoid distorting the casing. Air-lift pumping is considered the best method of perforating the filter screen about the perforator, because any other type of pump that would deliver a sufficiently large volume of water from this casing would suffer from the large amount of sand and gravel removed with the water.

The sections of casing pipe must have smooth, square ends and the inner diameter of the outer shell must be exactly the same as the outer diameter of the inner tube. When the pipe fulfills these conditions 10 to 15 tons pressure and considerable hammering is required to force the units of the outer shell over the inner one. When a unit has been forced into place it is fixed in position by denting the casing with a pointed pean hammer or a pick. Considerable difficulty was experienced by the Board of Water Supply in securing pipes to satisfactorily meet these requirements. In California the making of such pipes has become a small industry. The sheets are first cut to the right size with smooth edges. One side is punched with a multiple machine and the holes for the other side are then fixed from these by putting the two end holes over studs. The sheets are then rolled over a mandrel and riveted with flat, thin-headed rivets. When properly made these casings are very strong; an 8-in. shell 2 ft. long, made of No. 12 steel, has carried 240,000 lb. or 84,000 lb. per square inch of metal. The cost of double casing for a 12-in. well is about $1.25 per foot in California.

A starter about 17 ft. long is put down first. This is ordinarily made like the regular casing, but the metal is two gauges heavier than that in the rest of the well and all the units are riveted together and a steel cutting shoe is provided. A 17-ft. starter for a 10-in. well usually costs about $28.00; the cost of a starter for a 14-in. well is about $35.00. Extra heavy triple-ply starters sometimes cost as much as $150.00.

On account of difficulty in securing many of the parts of the driving outfit used on Long Island, the cost of the rig was somewhat in excess of what such outfits usually cost in the West. The cost of a complete outfit is usually estimated at between $3,500 and $4,000, being distributed somewhat as follows: Derrick frame with truck, $550; operating gears, $500; 12-h.-p. engine, $300; high-pressure pump, $250; boiler (mounted on derrick), $250; two pairs of jacks, $600; three driving heads, $90; sand buckets, link jars and cables, $500; tackles, fittings, pipe and the like, $550.

The crew required to operate such a well rig consists, in general, of a foreman and two laborers. Near Los Angeles, Cal., the cost of such wells, 10 or 12 in. in diameter and not more than 150 to 200 ft. deep has been $1.50 to $2.00 per foot, including the contractor's profit. Wells of larger diameter cost more owing to greater cost of the casing, the heavier tools used and greater difficulty in preventing distortion of the casing. The difficulties encountered generally increase with the depth and contracts for the smaller wells are ordinarily made at rates of $1.50 per foot for the first 200 ft., $2.00 per foot for the next 100 ft., $2.50 per foot for the next 100 ft., and so on. When many boulders or hard clay are encountered the cost may reach $5.00 per foot, but this is unusual.

The work of the New York Board of Water Supply is carried on under the general direction of Mr. J. Waldo Smith, chief engineer, and Mr. Alfred D. Flinn, department engineer, of Headquarters Department. Mr. Walter E. Spear, division engineer in charge of the Long Island Department, to whom this journal is indebted for the information herein given, exercises personal supervision over the well drilling work described.

THE WATER SUPPLIES of Kansas cities are reviewed in a recent report by Mr. Wm. C. Hoad, engineer of the State Board of Health. He reports that 36 cities with a total population of 293,000 draw their supplies from rivers and small streams; nine cities with a total population of 25,000 draw their supplies from lakes and ponds; 50 cities with a total population of 208,000 draw their water from shallow wells; 22 cities with a total population of 72,600 draw their supplies from deep wells. In 17 of the cities having surface supplies, no attempt is made to purify the water in any way. In six cities with a total population of 50,000 the water is subjected to plain sedimentation; in six cities with a population of 59,000 sedimentation with coagulation is practiced, while in ten cities with a total population of 137,000 filtration is conducted. A few of these purification plants are managed in a careful manner, but the report indicates that Mr. Hoad does not put much reliance on the efficacy of purification in most places.

The Beginning of Train Service Under the Hudson River at New York.

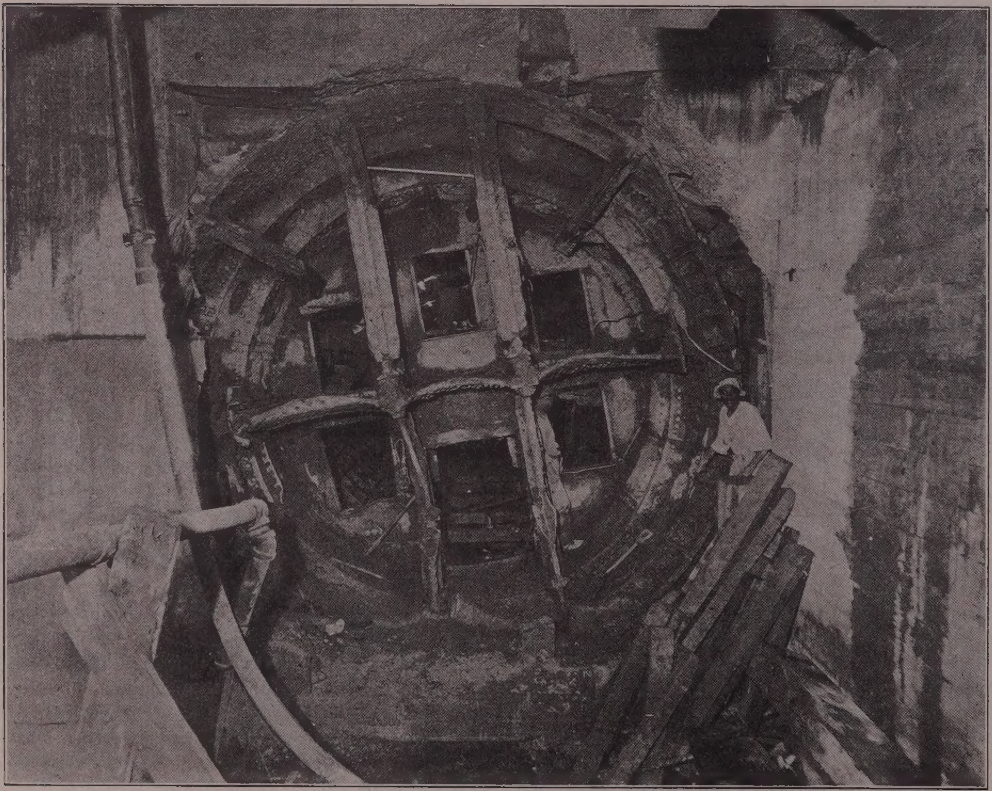
The formal opening of the Morton Street twin tunnels of the Hudson & Manhattan Railroad on Tuesday of this week was an event of more than ordinary interest to engineers as well as to the thousands of people who cross the river between Manhattan Island and the neighboring New Jersey cities. This new transportation line is not the first subaqueous railway into Manhattan, to be sure, for the tunnel under the Harlem River from the Bronx and the tunnel under the harbor from Brooklyn have been in service for some time. The Morton Street route has a special interest, nevertheless, as a long-needed link between New Jersey and Manhattan, which have lacked the bridge connections existing between the New York boroughs and have been forced to put up with ferries, which are slow and land their passengers in Manhattan at points inconveniently situated for making quick trips to many important business districts of the island. The opening of the line has an additional interest to the engineer, as it marks the successful completion of an enterprise that for many years proved beyond engineering and financial resources.

The division of the Hudson & Manhattan Railroad opened this week between New York and Jersey City is the northern line shown on the map, with the extension on the New Jersey side to the Delaware, Lackawanna & Western Railroad station and on the New York side to Sixth Avenue and Nineteenth Street. While the tubes are operated by the Hudson & Manhattan Railroad Company, they were constructed by an allied corporation, the Hudson Companies. The land and subaqueous tunnels thus put into operation are but part of an extensive system of passenger subways and tunnels on both sides of the Hudson River, with approximately 18 miles of single tube, having connections with the Pennsylvania, Erie and Lackawanna depots on the west bank of the Hudson and reaching northward in Manhattan to Thirty-third Street and Sixth Avenue. The system includes not only the twin river tunnels at Morton Street, but also another pair of single-track tunnels extending from the Pennsylvania station in Jersey City to a large new terminal building at Cortlandt and Church Streets, in the lower end of Manhattan Island. Connections will be made between the new system and the New York Rapid Transit subway system at two points, one at Dey Street, by a foot passage to the Fulton Street subway station, and the other by twin tubes under Ninth Street to a point just north of the present Astor Place subway station. The extension westward in Jersey City from the river contemplates stations at Summit Avenue and Newark Avenue, where the cars will come to the surface and run over the existing Pennsylvania tracks to Newark. The complete layout is clearly shown in the accompanying map.

Work was started on the Morton Street tunnels in November, 1874, by the Hudson Tunnel Railroad Company, of which the late DeWitt C. Haskins was president and manager. The plans laid down by Mr. Haskins contemplated a two-track brick tunnel, but before the work had progressed very far a change to two tubes was decided upon. A brick shaft 30 ft. in inside diameter was sunk on the New Jersey side near the river bulkhead line and an opening cut through it to start the tunnel. Many difficulties were encountered and it was found that the sinking of the shaft had so disturbed the surrounding ground that it was too large an undertaking to start the full tunnel section at the shaft. At the suggestion of the late Chas. B. Brush, a tube 6 ft. in diameter was therefore started and enlarged in funnel-shape as it progressed, ending in the full section, about 19 ft. in diameter, in a distance of 30 ft. From this point the two separate tunnels were started. In addition to the difficulties experienced in the caving ground the regulation of the compressed air, which is said to have been first used for horizontal tunneling in this work, occasioned considerable difficulty. The original plans for a single tunnel contemplated a height of 24 ft. and a width of 26 ft.; when the plans were modified to provide for two tunnels, a height of 18 ft. in the clear and a width of 16 ft. was adopted for them. A detailed account of the difficulties encountered at this time was given in a communication from Capt. John F. Anderson, the originator of the Anderson or pilot system of tunneling, in The Engineering Record of Aug. 17, 1895.

The method of tunneling consisted in advancing the heading without any protection against caving except the air pressure against the wall of silt. The lining was composed at first entirely of brick, but so much difficulty was found in confining the air that Captain Anderson suggested the use of flanged iron plates. Their purpose was to hold the air pressure until the brick lining could be built, and since their thickness was but ¼ in., they were not relied upon save for the temporary construction purpose.

Early in 1880 an improvement upon the unprotected heading method of driving the tubes was put into operation, the pilot system, worked out by Captain Anderson, then superintendent of construction of the tunnel, being used. The pilot consisted of a tube from 50 to 60 ft. long, 6 ft. in diameter, the forward end of which projected some distance into the silt in advance of the heading, while the rear end was held centrally in the completed portion of the tunnel. It was made of interchangeable flanged plates which were removed from the rear and placed at the forward end as the work advanced. Heavy radial struts resting upon this pilot supported the flanged iron plates of the tunnel proper until the brick lining could be placed. This device proved successful in maintaining the grade of the tunnel, with which considerable difficulty had been experienced.



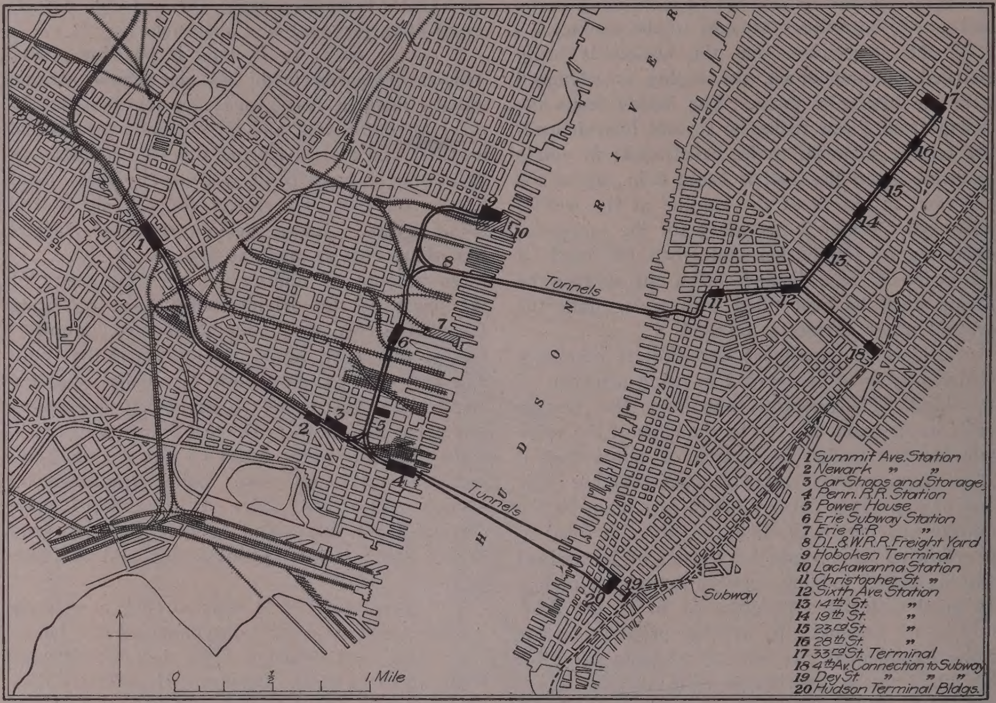
Shield Breaking through Concrete Bulkhead, Sixth Avenue and Twelfth Street.

About the time that the pilot was introduced it was decided to remove the temporary entrance from the shaft to the tunnels and merge the tunnels into one near the shaft. While the work was under way on July 21, 1880, a blow-out occurred, in which twenty men were trapped in the tunnel and drowned.

On account of financial difficulties work was stopped in 1882. About 2000 ft. of the north tube had been finished on the New Jersey side, 600 ft. of the south tunnel on the same side of the river and about 200 ft. of the north tunnel on the New York side.

The work was allowed to stand idle in this condition until Aug. 12, 1889, when the work was resumed with English capital, S. Pearson & Sons, of England, having taken the contract, with Sir John Fowler and Sir Benjamin Baker as consulting engineers. The new owners abandoned masonry lining and substituted instead heavy cast iron flanged plates. The pilot system was also discarded and the shield method substituted; the methods of connecting the old and new work were described in this journal on April 12, 1890. It was in connection with this shield that E. W. Moir, who was in charge of the work for S. Pearson & Sons, devised his hydraulic erector for placing the heavy cast-iron plates. The apparatus was fully described in an article in The Engineering Record of Oct. 25, 1890.

Work on the north tube from the New Jersey side continued until June, 1891, when lack of funds again caused the suspension of the work. The English company had finished about 1900 ft. of iron-lined tunnel, making the total length of the north tube about 3900 ft.

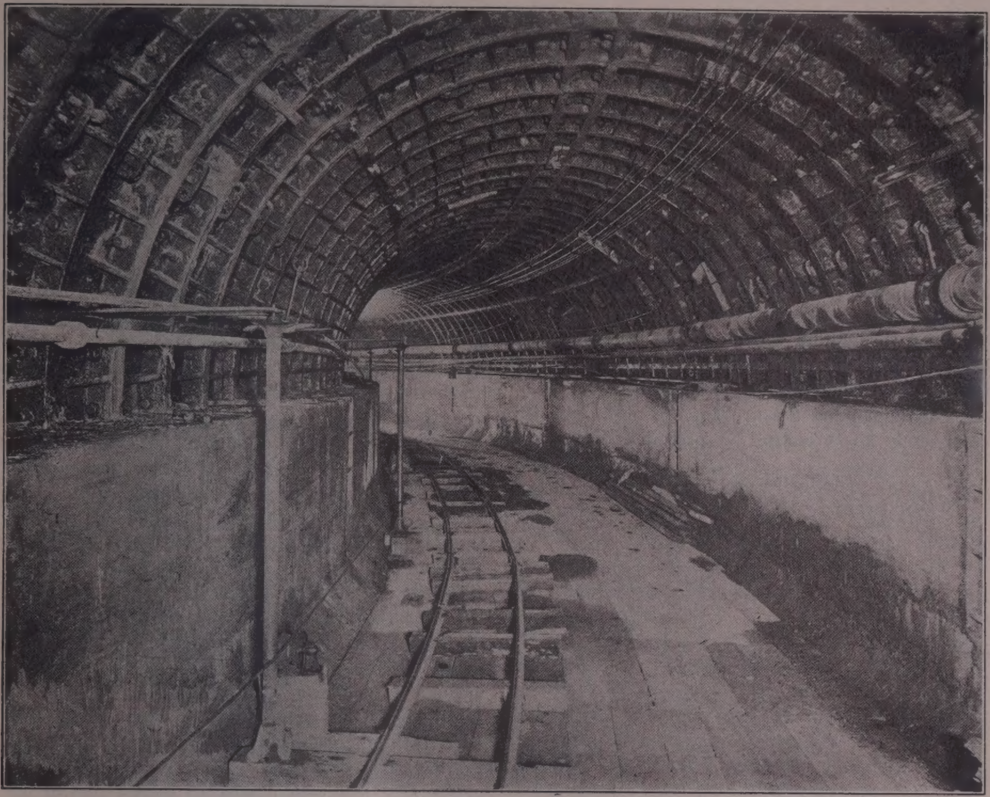


Subways and Tunnels of the Hudson & Manhattan Railroad Company.

In 1902, the tunnels having passed into new hands, work was resumed by the Hudson Companies, with Charles M. Jacobs, chief engineer, and J. Vipond Davies, deputy chief engineer. The shield which had been used by S. Pearson & Sons was extensively remodeled, the most important change being the addition of a movable cantilever platform to afford protection for the men drilling the rock, which in places projected up above the bottom of the tunnel and had to be blasted out. A shield was also built for the south tunnel and since that date the work has been prosecuted to a successful conclusion. The shields for much of the distance were pushed through the silt without any excavation. A complete description of the shield and of the methods followed on much of the work were published in The Engineering Record of July 25, 1903.

Shields of different sizes were used in the two tunnels, the interior minimum diameter of the completed tubes being 15 ft. 3 in. The depth of the bottom of the tunnel below the surface of the Hudson River varies from 60 to 90 ft., while the distance from the roof of the tunnel to the bed of the river ranges from 15 to 40 ft. For the greater part of the distance under the river the tubes are on about 30-ft. centers.

In connection with the New Jersey end of the tunnels an interesting piece of construction was carried out in the Y's which join the tubes with the subways running parallel with the river to connections with the three railroad terminals. The connection between the river tubes and the north and south tracks has been made in both directions, and in order to avoid the grade crossings that would have resulted if this had been made in the ordinary way the tracks for traffic in different directions were placed on different levels 24½ ft. apart vertically. This construction would have been very complicated in the soft wet ground, more than 80 ft. below the surface, if it had been carried out by ordinary tunneling methods. A short section of the structure where the lines converge and intersect was, therefore, isolated from the rest for construction purposes and closed with a solid mass of masonry pierced horizontally by an upper and lower chamber in which the connections are made with the land and river tunnels. This structure was built upon the surface of the ground as a huge double-deck caisson, the material being reinforced concrete. It was five-sided, about 101 ft. long, varying from 23½ to 46 ft. wide, and about 51½ ft. high above the cutting edge. A description of this interesting construction was given in The Engineering Record of Sept. 29, and Oct. 6, 1906. Two similar caissons were used at the other ends of the Y's connecting with the lines parallel to the river.

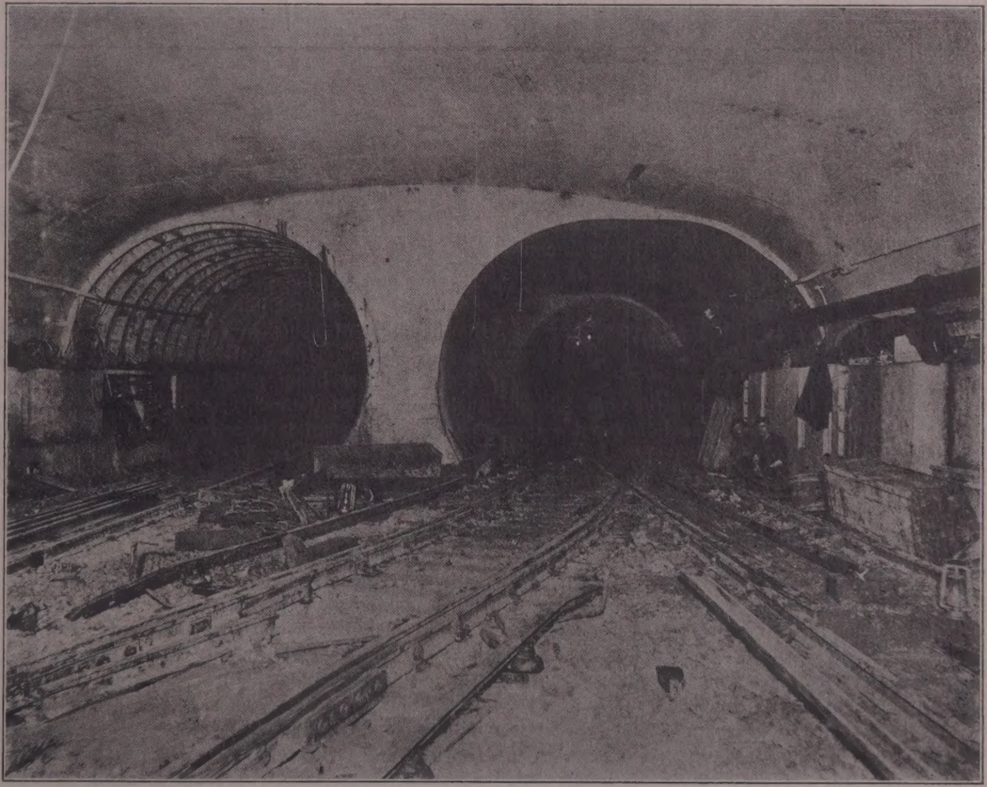


Curve at Morton and Greenwich Streets, Hudson & Manhattan Railroad.

Views of the completed tunnels, one of the stations and the cars used, were given in the Current News Supplement of The Engineering Record on Jan. 11, 1908.

The final construction work was carried on by the Hudson Companies, of which Walter G. Oakman is president. The operating company is the Hudson & Manhattan Railroad Company, Wm. G. McAdoo, president. Chas. M. Jacobs is the chief engineer for the construction company and J. Vipond Davies, deputy chief engineer. The financial part of the enterprise is being handled by the banking house of Harvey Fisk & Sons. The Hudson Companies has a paid-up capital of $21,000,000, and in addition to Hudson & Manhattan Railroad Company securities received in payment for construction, owns over $5,000,000 worth of property in New York City.

The Weight of Roof Trusses of both timber and steel is given fairly closely by the formula $W = S/25 + S^2/6{,}000$, in which S is the span in feet and W is the weight of the truss in pounds per square foot of horizontal projection of the roof. This formula has been devised by Prof. N. Clifford Ricker, of the University of Illinois, from an elaborate study of roof trusses described in a report issued by the Engineering Experiment Station of the University.



Crossover near Sixth Avenue Station, Hudson & Manhattan Railroad.

Book Notes.

Several years ago, Mr. H. Bamford, lecturer on engineering drawing and design at Glasgow University, investigated the methods employed in the preparation of tables of equivalent uniform live loads for railway bridges and devised a graphical method whereby, on a single diagram, the maximum shears and bending moments and the points along the span at which they occur can be determined with facility for a wide range of spans and for any given type of train. This method was outlined in four articles in "Engineering" in the fall of 1906, which have now been reprinted with additional matter in a book entitled "Moving Loads on Railway Underbridges." In the first chapter, the author gives a general discussion of bending moments and shearing forces in beams, and in the second and third chapters he explains the construction of diagrams of these moments and forces due to dead and live loads. The fourth chapter explains his graphical method of determining the maximum bending moment and shear due to live loads, and the fifth chapter describes the steps of the corresponding analytical method. In the sixth chapter, diagrams of maximum bending moments are discussed and in the seventh chapter there is a similar treatment of diagrams of maximum shear. The book forms a concise and interesting discussion of the subject (New York, The Maxmillan Co., $1.25.)

Power plant owners and designers will find much to interest them in three pamphlets recently issued by the U. S. Geological Survey. The first is a collection of "General Papers on the Producer Gas Power Plant, the Coal Briquetting Industry and Coal Mine Sampling." The first part gives a summary of the producer gas tests made at St. Louis and a compendium of information from manufacturers and users of producers. The second part gives a list of briquetting plants in this country, with descriptions of some of them, which indicate that there is a good chance of profit for such works in some parts of the country. The third part contains a table of analyses of both mine and car samples of coal from many sources and a discussion of the causes of the differences between them and of methods of overcoming them. The second pamphlet is on "Burning Coal Without Smoke in Boiler Plants," and was written by Mr. D. T. Randall, engineer in charge of the smoke-abatement experiments of the Survey. It summarizes the results of tests made at St. Louis, explains the causes of smoke and the principles on which preventive measures must be based, and gives a bibliography of books and papers on the subject. The third pamphlet, "The Purchase of Coal Under Government and Commercial Specifications on the Basis of Its Heating Value," is an important summary by Mr. Randall of what is being done by large purchasers of coal in this country to secure value for their money. The subject is rapidly forging ahead toward a most important place among power plant topics, which makes the pamphlet a particularly timely one.

A handbook of "Designing Tables" for draftsmen engaged on concrete steel work has been prepared by the Gabriel Concrete Reinforcement Company, 1201 Penobscot Building, Detroit, Mich. The introductory section is a discussion of the formulæ preferred by the company, which include the Talbot formula for the position of the neutral axis in beams and the New York Bureau of Buildings' formula for columns. The company's reinforcement is made of high carbon steel having an elastic limit of at least 60,000 lb., an ultimate strength of 110,000 to 120,000 lb. and an elongation of about 12 per cent in 4 in. For beams the reinforcement consists of straight tension rods and a system of vertical and inclined rods connected firmly to the others to take up shear and diagonal tension. Concrete has been figured as carrying 650 lb. in compression and nothing in tension. The tables are unusually comprehensive and may be summarized as follows: No. 1, areas of 1 to 12 round rods from ¼ to 1¼ in. in diameter, and weight per foot of each of the 15 sizes of rods within these limits. No. 2, weight of concrete per running foot of beams between 8 x 6 and 24 x 48 in. No. 3, footings for different loads and for 2000 to 9000 lb. bearing value of the soil. No. 4, safe loads for columns ranging from 8 x 8 to 25 x 25 in.; the table gives the reinforcement required as well as the loads. No. 5, safe loads per square foot for tile and concrete floors with spans of 5 to 25 ft. and various sizes of reinforcement. No. 6, safe loads per square foot for reinforced concrete floors. No. 7, resisting moments in inch-pounds of T-beams. No. 8, total loads per running foot carried by reinforced concrete beams. No. 9, steel required for beams with Gabriel "complete trussed" reinforcement. No. 10, dimensions of bent rods in beams from 12-in. depth and 10-ft. span to 36-in. depth and 26-ft. span. No. 11, weight in pounds per square foot of floor slabs. No. 12, weight in pounds per cubic foot of building materials. The company states that while it was perfectly satisfied regarding the accuracy of these tables several years ago, it did not feel warranted in publishing them before it was able to refer to a large number of important structures in which tests and careful observations have proved the reliability of the information. The book contains references to many of these structures.

Letters to the Editor.

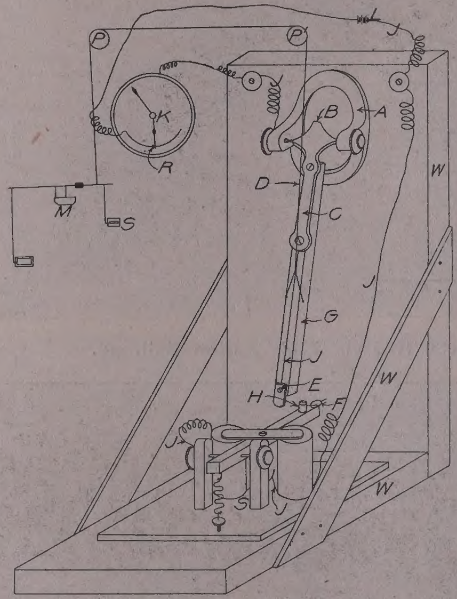
Burning Ashes.

Sir: Will you kindly give me the composition of the mixture which has come into use for the burning of ashes. Yours truly,

Niagara Falls, Feb. 8. Chas. B. Bradley.

[This inquiry was probably caused by the misleading newspaper reports regarding the utilization in the New York City public schools of the unburned fuel in ashes from the heating plants. The fuel used for heating the large number of school buildings in the city is for the greater part broken anthracite coal, of which a total of nearly 100,000 tons is used annually, and comparatively large amounts of unburned fuel are, with ordinary methods of firing, found to pass through with the ashes, ranging, it is stated, from 10 to 20 per cent. of the bulk of the ashes. An investigation was made of this source of loss by the Department of Supplies of the Board of Education, of which bureau Mr. Patrick Jones is superintendent, and, as a result, the plan was devised of refiring the ashes direct from the ashpit to the furnace, and unchanged except for moistening with an oxalic acid solution. This plan was tried in several buildings of the department in the winter of 1906-7 with results so satisfactory to the Bureau that it was generally introduced in the heating plants of all buildings of the department at the beginning of the present winter. The results have so far, according to Superintendent Jones, been very satisfactory for the greater part, indicating the possibility of a material saving in the annual fuel bill.

The instructions that have been issued to the janitors by the Bureau direct that the solution be prepared by dissolving oxalic acid and rock salt in hot water in the proportions of two ounces of the acid and one pound of the salt to each gallon of water, and that it be applied to the ashes by sprinkling lightly with an ordinary sprinkling can, but not in such quantity as to form a pasty mass. After the fires are cleaned in the morning, it is directed that enough fresh coal be spread on the fuel bed to form a good body of fire, after which, when it becomes necessary to refire, the ashes at hand are sprinkled and spread on the fire to a thickness of 1½ to 2 in. This procedure is followed throughout the day unless the fire gets low, when fresh coal is added. The last covering of the day is, however, ordered to be fresh coal so that in banking the fire for the night, a sufficient body of fire will be provided to permit cleaning and starting up without difficulty in the morning. No instructions are issued regarding the handling of ashes in which no further unburned carbon is found, the discretionary powers of the janitors being relied upon to throw out such portions of the ash.



Heater Regulating Device.

The new system is now in use in 232 of the schools in Greater New York, and reports of successful results have been received by Superintendent Jones from 155 of the plants; of the remainder, the reports show that in 26 plants the results are as yet incomplete or indefinite, in 27 cases poor results, and in 24 cases entire failure. It is pointed out, however, that many of the janitors making successful use of the process, report savings of fuel ranging from 15 to 50 per cent., although the opinion is offered by Mr. Jones that there are few cases where conditions will permit a saving of over 20 per cent., while the average saving expected will not exceed 10 per cent. The extent of such a saving as this may be realized from the fact that, with the present fuel cost of approximately $500,000 annually if applied to the entire department, it would effect an economy of $50,000 per year.]

Regulator for a House Heater.

Sir: I have a device on my furnace to start it in the morning that has proved to be very satisfactory and efficient, and may be of interest to your readers. It is very simple in operation and cheaply and easily made. I have had mine in operation all this winter with the result that when I wake up in the morning my house is warm. The diagram shows how it is made and how it is wired.

All the material that is necessary is a 20-ohm telegraph instrument, an old clock and a few pieces of board from a packing box. The other things are found about any house.

First, take the key off the instrument, take the finger rest off the bar *C* and straighten it with a few blows of a hammer. Cut a stick *G* about 1 ft. long and screw it to the straightened bar *C* as shown. Make a bracket of wood *WW*, as shown, wide enough to hold the sounder *S*. Screw a piece of brass *E* on the end of *G* with a wire *J* fastened under and running up to and under *C*. Remove the sounder yoke so the sounder will be as shown. Take the adjusting screw out of the sounder bar and put it in upside down with a little of it filed off so that it will be as shown at *H*. Place the sounder on the bracket with a screw-eye *F* screwed into the back to keep the bar from going up too far. Place the screw-eye so that the sounder bar will have a range of about ¼ to 5/16 in. With the sounder in the position shown, screw the key base to the back, as shown, so that the brass piece *E* will catch behind *H* when the sounder bar is up as far as it will go and so *E* will pass easily over *H* when the sounder bar is down as far as it will go.

Fasten the bracket to a wall conveniently near the furnace in the cellar so that the back is vertical. The sounder is to be screwed to the shelf when it is properly adjusted. With the bracket fastened to the wall, fasten a piece of picture wire to the damper regulator lever of the furnace (this wire is shown at *D*), and carry it over the pulley *P* to P^1, which must be placed just about in the plane of the face of the back and in a center line of the arm *G*. Carry the wire *D* about two-thirds of the way down the arm *G* and fasten it so that the back check-draft door is horizontal. Fasten a wire to the clock so that the hour hand can be put in circuit. Fasten a wire to the face of the clock and insulated from the clock. This can be done with a piece of electric bell wire and sealing wax, but there are a variety of ways of doing this depending on what materials are at hand. When the hour hand makes the connection, the current flows through the works of the clock, through the key down the arm *C* to *E* through *H*, through the sounder bar, thence through the electro-magnets of the sounder and through the batteries to the hour hand again. When the current passes through the magnets the sounder bar is pulled down and the arm *G* is released and flies up, allowing the back check door of the furnace to close and open the front draft door. The current that is necessary is used just for a small fraction of a second. Two dry batteries are all that is needed. Power can be obtained to open dampers in the smoke pipe by placing a weight on the horizontal back check draft door so that when the arm is released the weight will fall off and pull open the dampers. This device can be made and put up in about a couple of hours, and is inexpensive and durable and easy to set. The arm *G* is so light that it will not interfere with a damper regulator of a steam or hot-water boiler.

Yours truly,

Lawrenceville, N. J., Feb. 18. P. W. Kafer.

The Old Pennsylvania Station in Washington at Sixth and B Sts. has been deeded to the government, and the railroad surrenders all right to use any part of the Mall. In accordance with the agreement the sum of $1,500,000, which the government is to contribute to the cost of the new station, now becomes payable.